

The carbon dioxide passed through the 3/4" pipe is then 132.4 lb vs. 225 lb allowable, flow through the 1 inch pipe is 300 lb vs. 300 lb allowable, and flow through the 1 1/4" pipe is 600 lb vs. 600 lb allowable. Pipe sizing is, therefore, also satisfactory.

#### A.8. PRESSURE INCREASE

A simple and reasonably accurate method for estimating the pressure increase due to the release of carbon dioxide into very tight spaces is as follows:

##### Assumptions:

- (1) Carbon dioxide expands to 9 ft<sup>3</sup> for each pound of CO<sub>2</sub> in bottle (this is at 86<sup>0</sup>F).
- (2) Constant enthalpy for expansion from 3000 psia to 14.7 psia for CO<sub>2</sub>.
- (3) Complete and instantaneous mixing of CO<sub>2</sub> and air.

A.8.1 Determine the following conditions:

$$\text{Weight of CO}_2 = \frac{\text{Vol. of Void (ft}^3\text{)}}{\text{Vol. factor (ft}^3 / \text{lb CO}_2\text{)}}$$

##### For CO<sub>2</sub>:

$$V_b = 9 \text{ ft}^3 / \text{lb} \times \text{wgt of CO}_2 = (\text{volume CO}_2)$$

$$T_b = -180^0 \text{ F} + 460 = 280^0 \text{ R}$$

##### For Void:

$$P_1 = 14.7 \text{ psia}$$

$$V_2 = \text{Volume of void}$$

$$T_a = \text{Temp. of void prior to release of CO}_2. \text{ If not known, estimate to be } 150^0 \text{ F. (610}^0 \text{ R).}$$

A.8.2. Calculate T<sub>2</sub> for mixture of air and CO<sub>2</sub> in void:

$$T_2 = \frac{KT_a + T_b}{K + 1}, \quad \text{where } K = \frac{\text{volume factor}}{13.14}$$

A.8.3. Calculate partial pressures (P<sub>2</sub>CO<sub>2</sub> & P<sub>2</sub> air)

$$P_2 \text{ CO}_2 = \frac{P_1 V_b T_2}{T_b V_2} \quad P_2 \text{ air} = \frac{P_1 T_2}{T_a}$$

A.8.4 Sum of partial pressures equals total absolute pressure in the space (P<sub>T</sub>).

$$P_T = P_2 CO_2 + P_2 air$$

#### A.9. FREE VENTING

For very tight enclosures, the area necessary for free venting may be calculated from the following formula, assuming the expansion of carbon dioxide to be 9 ft<sup>3</sup>/lb.

$$X = \frac{RA}{1.3\sqrt{P}}$$

where: X = free venting area in square inches.

R = rate of injection in lbs/min/in<sup>2</sup> of orifice area (use 1400).

P = allowable strength of enclosure in lbs/ft<sup>2</sup> (use 25 if not known).

A = total orifice area in square inches.

#### A.10. CYLINDER LOCATION

Cylinders shall be located outside the protected space and shall not be subject to being cut off in event of fire. The only exception to this rule is that a total-flooding system of 300 pounds or less, with approved automatic release, may be installed in the protected space. Spaces containing the cylinders shall be designed and ventilated so as to preclude an ambient temperature in excess of 130°F. This is to prevent the carbon dioxide pre-sure in the cylinders from rising, and possibly breaking the rupture disc which protects the cylinder from over-pressure.

A similar over-pressuring situation might arise if cylinders are located immediately adjacent to the space which they protect. Heat from a fire in the protected space might readily be conducted through the bulkhead, over-pressuring the cylinders. This situation could occur if the fire has gained a considerable head start before discovery. In such a situation, rupture of the over-pressure disc would fill the cylinder room with CO<sub>2</sub>, leaving none to fight the fire. To avoid such a situation, the CO<sub>2</sub> cylinder bank should be located in a space that is not contiguous with the space protected. If this is impossible, the common bulkhead(s) between the spaces should be protected with A-60 structural insulation.

#### A.11. REMOTE RELEASE

When remote stations are installed which will control either release of the required amount of carbon dioxide, or which will operate a direction valve to direct CO<sub>2</sub> into the proper compartment, design of the remote control system design should be carefully considered. Usually the remote control operation is accomplished by a cable system. A lever is pulled at the remote station, and this force is transmitted via the cable to the cylinder location where cylinders or valves are operated. Operation of the remote pulls should not require more than 40 pounds pull nor more than 14 inches movement to accomplish its purpose. Although the system may operate satisfactorily when new, kinks in the cable due to being kept in one position, or possible deterioration of pulleys, etc. may make the system more difficult, or impossible, to operate in the future. For this reason, excessive lengths of control cable should not be used, and cables and other operating mechanisms should never be installed in locations where they will be subject to the weather.

#### A.12. AUTOMATION

On automated vessels a centralized engineroom control station is provided. If the control station is enclosed, there are at least two major areas of concern:

- (1) If a fixed carbon dioxide extinguishing system is installed for protection of the machinery space, the predischage warning alarm should be capable of being heard inside of the control station as well as in the machinery space.
- (2) The remote operating controls located at the engineroom" exit for the fixed extinguishing system should be duplicated within the control station enclosure.

## B. DESIGN AND REVIEW OF SYSTEM

Application: Passenger & Tank Vessels contracted for on or after January 1, 1962

Cargo Vessels contracted for on or after November 19, 1952

Note: Numbers in brackets refer to applicable subparts of the regulations. (Passenger - Part 76; Cargo - Part 95; Tank - Part 34, unless otherwise noted)

In case of any doubt, applicable regulations should be consulted for exact wording of requirements.

- B.1. Check space to be protected and determine type of system to be installed (See chart, Subpart C).
- B.2. Check volume of protected space(s). Be certain boundaries are sufficiently tight to maintain CO<sub>2</sub> concentration (.15-5(e)(2), .15-5( c)(2)). M additional amount of one pound of CO<sub>2</sub> for every square foot of opening which cannot be closed at the time of extinguishing (clear door opening) is required Very tight spaces such as paint lockers, etc. may require pressure relief (.15-40(a)). (For estimate of pressure increase, see Subpart A, Discussion).
- B.3. Determine volume factor for space(s) and determine quantity of CO<sub>2</sub> required (see chart, Subpart C).
- B.4. Compare amount of CO<sub>2</sub> required for space requiring greatest amount, to quantity of CO<sub>2</sub> to be provided (.15-5(b)).
- B.5. Control and cylinder location shall be outside of the protected space and in an accessible location (control .15-10(a), cylinder .15-20(a)). In systems of 300 pounds or less, cylinders may be located inside of protected spaces if automatic discharge is provided (.15-20(b)). Such installations should also have a manual release operable from outside of the space, and not subject to being cut off.
- 8.6. Cylinders should be securely mounted (.15-20(d)) and easily removable for weighing (.15-20(e)). They should not be subject to an ambient temperature in excess of 130°F.(.15-20(c)). They should also be protected from excessive temperatures in event of fire in the protected space.
- B.7. Each cylinder must be provided with a safety device (rupture disc) to relieve excessive pressure. Similarly, where a distribution manifold is used, a pressure relief device is required (.15-15(d)) to protect the piping in event all branch line shut-off valves are closed.

- 8.8. Check whether nozzle locations will give a relatively uniform discharge (76., and 95.15-5(e)(S), 34.1S-S(e)(6)).
- 8.9. Compare nozzle outlet area (total) with main supply pipe size or nominal cylinder outlet area, whichever is smaller (7b., and 95.15-5 (e)(6), 34.15-5(e)(7)). The nominal cylinder outlet area (in square inches) is equal to the quantity of CO<sub>2</sub> required (in pounds) times 0.0022.
- 8.10. Compare the carbon dioxide flow in each section of piping to the maximum allowable by the pipe size tables (76., and 95.1-5(e)(3), 34.15-5(e)(4)). For method of estimating carbon dioxide flow in branch lines, see discussion, Subpart A.
- 8.11. For machinery and similar spaces and specially suitable spaces, discharge of the required amount of carbon dioxide must be completed within 2 minutes (76., and 95.15-S(e)(7), 34.15-5(e)(8)). This requirement will be met if nozzles and pipes are size according to (8) and (9).
- 8.12. Piping must extend at least 2 inches beyond the last orifice to reduce the danger of clogging the nozzle (.15-15(i)).
- 8.13. Piping passing through living quarters shall not be fitted with drains or openings in such spaces (.15-15(i)).
- 8.14. Location of controls must be outside of the protected space (.15-10 (a)) and convenient to one of the main means of escape (.15-10(c)).
- 8.15. CO<sub>2</sub> distribution piping shall be controlled from not over two stations (.15-10(c)). If cylinders are capable of remote release, provisions shall also be made for local release at the cylinders (.15-10(e)).
- 8.16. At least 2 pilot cylinders are required in systems of 3 or more cylinders (one pilot cylinder in two cylinder systems), which depend upon gas pressure for release of rest of cylinder bank (.15-10(e)). Manual controls shall require a pull of not more than 40 pounds (force) nor a movement greater than 14 inches. Estimate about 10 pounds per cylinder.
- 8.17. Machinery space shall have one control to operate the valve to the space and a separate control to release at least the required amount of CO<sub>2</sub> (.15-10(d)).
- 8.18. Complete but simple operating instructions should be located near the release control (.15-10(h)).
- 8.19. Check ventilation arrangement and shutdown. Mechanical ventilation requires automatic shutdown (.15-35(a)). Means must be provided for closing all natural ventilation openings (.15-35(b)). Canvas is satisfactory.
- 8.20. A delayed discharge and predischage alarm shall be provided for systems protecting spaces normally accessible to persons on board except lamp rooms, paint rooms, and similar spaces (.15-30(a)). The 20 second delay period prior to discharge of the carbon dioxide specified in, the regulations is the minimum delay period. In large or unusually arranged spaces, the delay period should be sufficient to allow escape from all portions of the protected space.

- B.21. The predischARGE alarm must be marked with a warning sign (78.47-9,97.37-9, 35.40-7). predischARGE alarm shall depend upon no source of power other than C02 flow (.15-35(a)). The alarm should be located so as to be audible throughout the space, while all machinery is operating.
- B.22. Check list of component part numbers as shown on the drawing against the Coast Guard approved parts list (.15-10(g), 15-15(a), (b) & (c), must be supplied by the same manufacturer. This will assure that the parts are compatible and will result in an effective system.
- 8.23. Pipe and fittings should be provided in accordance with the Coast Guard approved pipe drawing of the manufacturer. Where reference is made to specific approved drawings of piping and/or installations which are on file, additional copies must be provided for the use of the inspector in the field. In instances where pipe and fittings are provided by organizations other than the system vendor, a complete bill of materials for the system must be submitted.

## C. SPACES PROTECTED BY CARBON DIOXIDE &amp; TYPE OF SYSTEM REQUIRED

ABBREVIATIONS: R - Required  
 O - Optional in lieu of other systems  
 RII - CO<sub>2</sub> only system permitted, but not required  
 e - Some exceptions see regs

Type of Vessel	Space Protected by Carbon Dioxide	Type of System (For definition of systems Subpart A)	Flooding Factor	Required or Optional
CARGO & MISC.	Cargo Compartments	Cargo System	30	R*
	Spaces Specially Suitable for Vehicles	Total Flooding	22	R**
	Cargo Tanks	Cargo Tank System	30 (see Subpart A)	O
	Lamp & Paint Lockers & Similar Spaces	Total Flooding	See Table 95.15-5 (e)(1)	R
	Oil Fired Boilers and Associated Equipment	Total Flooding	See Table 95.15-5(e)(1)	O
	Internal Combustion Propelling Machinery	Total Flooding		RII R <sup>e</sup>
	Enclosed Ventilation Sys. for Motors & Generators of Elec. Propelling Mach.	Delayed Discharge Total Flooding	10(2000 ft <sup>3</sup> or less) <sup>o</sup> 12(over 2000 ft <sup>3</sup> ) <sup>o</sup>	R
	Dry Cargo Compartment	Cargo System	30	O
TANK	Lamp & Paint Lockers & Similar Spaces	Total Flooding		O
	Pump Rooms	Total Flooding	See Table 34.15-5(e)(1)	O
	Boiler Rooms	Total Flooding		O
	Machinery Spaces	Total Flooding		R-If Flash Pt. Less than 110°F RII R <sup>e</sup>
	Internal Combustion Installations	Total Flooding		R
	Enclosed Ventilation Sys. for Motors & Generators of Elec. Propelling Mach.	Delayed Discharge Total Flooding	10(2000 ft <sup>3</sup> or less) <sup>o</sup> 12(over 2000 ft <sup>3</sup> ) <sup>o</sup>	R
				II(CO)

Type of Vessel	Space Protected by Carbon Dioxide	Type of System (For definition of systems Subpart A)	Flooding Factor	Required or Optional
PASSENGER	Paint & Lamp Lockers & Similar Spaces	Total Flooding	See Table 76.15-5(e) (1)	R
	Boiler Spaces	Total Flooding		O
	Machinery Spaces (Internal Comb. & Gas Turbine)	Total Flooding		R
	Auxiliary Spaces (Internal Comb. & Gas Turbine)	Total Flooding		Re
	Cargo Spaces (Accessible During Voyage)	Not Permitted		
	Cargo Spaces (Inaccessible During Voyage)	Cargo System	30	R
	Cargo Oil Tanks	Cargo Tank System	30 (see Subpart A)	O
	Cargo Spaces Containing Autos with Gasoline	Total Flooding	22**	R
	Enclosed Ventilation Sys. for Motors & Generators of Elec. Propelling Mach.	Total Flooding	10(2000 ft <sup>3</sup> or less)* 12(over 2000 ft <sup>3</sup> )*	R

\* If accessible during voyage may be considered living space and sprinklers required.  
 \*\* If space partially open, sprinklers may be required.

° In addition, must maintain 25% concentration until equipment can be stopped.

\*\* If the deck is open at either or both ends, as found on ferry vessels, it is called a "vehicular deck" and a manual sprinkling system is required.

#### D. INSPECTION AND TESTING (Carbon Dioxide)

##### D.1. INSTALLATION TEST

In addition to determining that the system is installed in accordance with the regulations and approved plans, the following checks are suggested:

D.1.1. Piping should be pressure tested in accordance with paragraph 34.9 76., and 95.15-15(j).

D.1.2. Remote controls for release of carbon dioxide equipment should be operated. Excessive pull (over approximately 40 pounds) or movement (over approximately 14 inches) should not be permitted.

D.1.3. Protection of cylinders and controls from damage should be verified.

- D.1.4. Operation of discharge delay and alarm should be checked. Discharge of gas into spaces that may be occupied should be delayed for a period sufficient to allow escape from any portion of the space. Thought should be given to the audibility of CO<sub>2</sub> alarms in the engine room especially while the vessel is underway. It has been observed on occasion that the alarm could not be heard over the noise of an underway engine room. The alarm must be audible over all operating machinery to afford adequate protection to the crew.
- D.1.5. Operating levers, selector valves, etc. should be properly identified. Operating instructions should be examined.
- D.1.6. Switches for automatic shut down of ventilation should be operated.
- D.1.7. It should be verified that all openings into the space are capable of being secured.
- D.1.8. Check operating instruction book.

D.2. INSPECTIONS FOR CERTIFICATION

- D.2.1. Weigh cylinders. Recharge if weight loss exceeds ten percent of charge.
- D.2.2. Predischage alarm should be checked and test operated if necessary. The alarm should be audible throughout the space with the machinery operating.
- D.2.3. Compliance with items (1.2)) (1.6) and (1.7) above should be assured.
- D.2.4. Operating instructions should be in place and legible.
- D.2.5. Determine age of cylinders. If over 12 years old, cylinder should be discharged and hydrostatically tested. See 46 CFR 147.04-1(a). However, if cylinders are 5 years old or older and found underweight by D.2.1, then hydro must be conducted at the time cylinders are removed for recharging. Owners often have service contracts with carbon dioxide equipment manufacturers for maintenance of the system. A joint inspection is desirable, but does not relieve the Coast Guard of responsibility.
- D.2.6. If under D.2.5. any cylinders or piping are required to be inspected, then all flexible connections between the cylinders and the piping shall be renewed or subject to a pressure test of 1,000 pounds per square inch.
- D.2.7. Visually check all distribution lines for disformation, missing discharge heads, blanks, and breaks.



### III. MECHANICAL FOAM SYSTEMS

#### A. DISCUSSION

##### A.1. DEFINITIONS

###### A.1.1. Foam

A fire extinguishing agent which is a fluid aggregate of small air filled bubbles that will float on the surface of most flammable liquids. It is formed by mixing foam concentrate and water (foam solution) and expanding it by agitation with air.

###### A.1.2. Foam Solution

A homogeneous solution of foam concentrate in water. The term "water rate" is used in the Coast Guard regulations; its meaning is synonymous with that of "foam solution rate" for 3% and 6% concentrate systems.

###### A.1.3. Foam Concentrate

An aqueous solution of concentrated liquid (usually protein-base) with a stabilizer added which when mixed with water and air forms a fire extinguishing foam which is highly resistant to breakdown.

##### A.2. FOAM, CHARACTERISTICS & APPLICATIONS

Mechanical foam is produced by introducing foam concentrate in proper proportions into a flowing stream of water and aspirating with air. Aboard ship the foam concentrate is normally introduced by means of proportioning equipment near the foam concentrate storage container at some central location on the vessel. The foam solution thus formed is pumped through fixed piping to foam nozzles, monitors, etc. at the area to be protected. Air is mixed with the foam solution at the nozzle and foam produced.

Foam extinguishes a flammable liquid fire by forming a continuous blanket over the burning liquid, separating the combustible vapors from the oxygen (air) necessary for combustion. Because foam contains water dispersed in very thin film, it also has cooling properties. Once formed the blanket has the ability to reseal itself should it be broken. It is not readily dissipated by heat. The intended use of foam is against flammable liquid fires where a surface area is present which may be blanketed.

It is of limited use on most class A (wood, paper, etc.) fires due to its inability to effectively cover other than horizontal surfaces for long periods of time, its limited cooling ability, and its inability to penetrate deep seated fires. Foam may also be used to blanket flammable liquid spills which are not burning to prevent the escape of combustible gases and subsequent ignition.

The foam concentrate normally supplied is suitable for use with most, but not all, flammable liquids carried aboard tankers. For example, it is impossible for this foam to form a blanket on alcohol's, esters, ketones, or ethers (commonly called water-soluble or polar liquids).

An approved (Coast Guard) "polar solvent" foam concentrate is available, which is also suitable for hydrocarbon fires. Unlike other available alcohol foams, it is not necessary to spread this product gently on the surface. Rather, it can be applied through hose nozzles or monitors. In addition to the 20% "foaming concentrate", this system has a 3% catalyst, which further reacts the

polymer in the concentrate. The "polar solvent" foam is further strengthened upon application to the solvents, where regular foams are quickly broken down. The application rate must be determined for each individual vessel.

#### A.2.1. High Expansion Foam

Presently under consideration, is a new concept in fire extinguishing foams. High expansion foam is capable of producing vast volumes of foam with a small quantity of water and a very small amount of suitable foam concentrate. Where the expansion ratio of low expansion foam is about 8:1, the expansion ratio for high expansion foam is about 800:1. This type of foam system has some possible use for large volume spaces, where the quantity of CO<sub>2</sub> required would be excessive. This system has not yet been approved by the Coast Guard (although it has been accepted on an experimental basis for a single roll-on/roll-off vessel) and is not further discussed in this guide.

#### A.2.2. Light Water

An aqueous film forming foam called light water is also being investigated. This new synthetic foam forming concentrate has been developed for flammable liquid fires. Chemically the foam is a perfluorinated surfactant capable of enabling water to float on petroleum products. Even though the agent shows promise, such characteristics as burnback resistance, corrosiveness, sea water suitability, and adaptability to currently approval marine type foam systems have yet to be evaluated by the Coast Guard.

### A.3. NCENTRATE

#### A.3.1. Rate of Application

Regular foam concentrate is available as either 3% or 6% liquid. The usual ratio of foam concentrate, water, and air to produce a foam with good fire extinguishing properties is as follows:

3% concentrate - 3<sup>1</sup> parts concentrate, 97 parts water, 900 parts air  
 6% concentrate - 6<sup>1</sup> parts concentrate, 94 parts water, 900 parts air

The 3% concentrate is usually used in new installations since it requires about one-half the quantity of concentrate to produce an equivalent volume of foam. Cost for equal protection is comparable.

For "polar solvent" systems the proper proportions are as follows:

(20% concentrate type) - 3 parts catalyst, 20 parts foaming concentrate, 77 parts water, and 900 parts air.

The first fire-fighting foams available were the "chemical" type which depend upon a chemical reaction to form the foam. It was found by testing that a six inch blanket of chemical foam would

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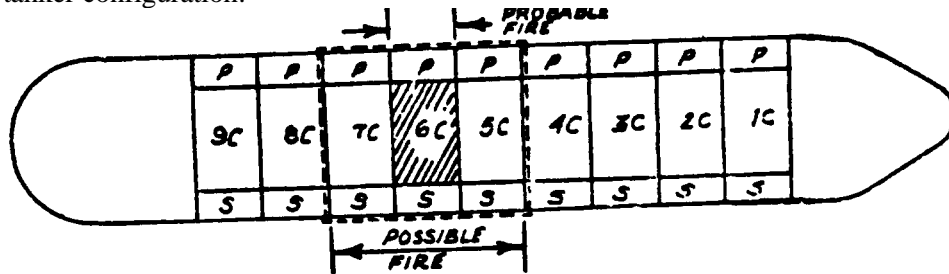
<sup>1</sup> In operation foam proportioning equipment usually introduces foam concentrate into water in proportions exceeding the minimum required (e.g. 3.05%). The amount of foam concentrate introduced varies with the water flow through the proportioned. The actual percentage may be determined by referring to the appropriate manufacturers' instruction booklet.

extinguish fires and be sufficiently resistant to beat breakdown. When the mechanical foams were first developed, this same criterion was applied (6" blanket) to determine what quantity of foam would be required. This has, over the years, become an acceptable design requirement, providing sufficient foam to remain intact for periods long enough to suppress vapor release and cool the liquid surface and adjacent ignition sources to prevent reignition. The requirement for a blanket of this thickness appears in the Coast Guard regulations as a minimum foam solution rate (water rate) for a specific period of time. This allows more uniform system design procedures. For example, for a boiler flat the required foam solution application rate is 1.6 gpm per 10 square feet for a period of 3 minutes. Assuming a conservative ratio of expansion of 8 (volume of foam to volume of foam solution) it will be seen

$$\frac{1.6 \text{ gal} / \text{min}}{10 \text{ ft}^2} \times 3 \text{ min} \times \frac{\text{ft}^3}{7.48 \text{ gal}} \times \frac{12 \text{ in}}{\text{ft}} \times 8 (\text{expansion}) = 6.16 \text{ in}$$

Note: One cubic foot of water contains 7.48 gallons that a 6.16" blanket of foam will be formed over the area protected.

For deck foam systems, the required foam solution rate differs from the required rate for fixed foam systems. The required rate is 0.016 8pm per square foot of the entire tank surface for 15 minutes. Entire tank surface is defined as the maximum beam of the vessel times the total longitudinal extent of tank spaces. The rate for deck foam; Systems is based on the following typical tanker configuration:



**Figure III.A.1. Typical T-2 Tanker**

It is a generally known fact that the effectiveness of a foam fire extinguishing system in controlling a flammable liquid fire depends upon the rate at which the foam is applied. Most systems are designed to deliver 0.16 gpm for each square foot of protected hazard. The figure of 0.16 gpm/ft<sup>2</sup> of protected hazard is used in Coast Guard regulations governing installation of foam extinguishing systems in boiler rooms. For deck foam systems, however, the rate of 0.16 gpm/ft<sup>2</sup> of protected hazard is expressed in a different way, i.e., deck foam Systems are required to deliver 0.016 gpm per square foot of the total tank area of a vessel's cargo tanks. The figure of 0.016 gpm/ft<sup>2</sup> of total area was derived from the rate of 0.16 gpm/ft<sup>2</sup> of protected hazard, based upon the design of a T-2 tanker and the probable area of fire spread aboard the vessel. Calculating the required foam system rate for a T-2 tanker using the rate of 0.016 gpm/ft<sup>2</sup> of total tank area, one finds the resulting system would be capable of delivering about 0.16 gpm/ft<sup>2</sup> of area to any series of adjacent port-centerline-star-board tanks extending the breadth of the vessel. Thus, for a T-2 tanker, the accepted rate of 0.16 gpm/ft<sup>2</sup> of protected hazard is still available. Again, using the 0.16 gpm/ft<sup>2</sup> of total tank area to design the deck foam system aboard a T-2, one finds the resulting system will deliver 0.252 gpm/ft<sup>2</sup> of any single cargo tank. As design of tank vessels evolved, however, the trend has been toward fewer and fewer tanks. It can be seen from the foregoing explanation that using the rate of 0.016 gpm/ft<sup>2</sup> of total tank area for design of the deck foam system for a vessel having

fewer tanks than a T-2 would mean any single tank aboard that vessel would be protected by a lower application rate. Thus, with no change in the method of calculating foam application, fewer tanks means a lower foam application rate for each tank with a resultingly serious compromise in the effectiveness of the foam system. Therefore to correct this situation a dual method of calculating deck foam system application rate is used. For usual petroleum products the water rate shall be at least 0.016 gpm for each square foot of the cargo area or 0.24 gpm for each square foot of the horizontal sectional area of the single tank having the largest such area, whichever is greater. The quantity of foam shall be sufficient for 15 minutes of operation. The cargo area is defined as the maximum beam of the vessel times the longitudinal extent of the tank spaces.

The rate was arrived at as follows:

- (1) Assume fire in no. 6C as shown.
- (2) The probable fire and possible fire areas would also be as shown.

The total possible fire area is seen to be approximately one third of the total tank area of the vessel. The requirement for application of the required rate for 15 minutes was based upon two consideration:

- (a) If the fire burned beyond 15 minutes<sub>1</sub> it is improbable that it could be contained and extinguished by the vessel's crew, and
- (b) Previous requirement for fixed-systems in cargo tanks was to apply the tam solution for 5 minutes for one tank across. Since the possible fire area covers three tanks across, the required application time would be  $3 \times 5 = 15$  minutes.

Thickness of foam blanket, per se, has no meaning. What is important is an ability to extinguish a fire and maintain an effective vapor-tight cover. Some foams require thicker blankets to accomplish this. Other foams can do an equally effective job with blankets of lesser thickness. Thus rate of application<sub>1</sub> related to some standard test rate, is the important factor and not thickness of blanket.

Actual small scale fire tests conducted for Coast Guard approval of foam concentrate and associated equipment were conducted at a rate of 0.06 gpm/ft<sup>2</sup>, these fires were extinguished. Thus the required rate of 0.16 gpm/ft<sup>2</sup> (compared to 0.06 gpm/ft<sup>2</sup> test rate) provides an adequate safety factor to account for large scale fires and/or larger preburn for shipboard installations.

### A.3.2. Quantity Required

The amount of foam concentrate required to be supplied depends upon the type of installation. Systems designed to protect machinery and similar interior locations where the foam blanket will be contained within the space require calculation of the quantity of foam concentrate by one method. neck foam systems protecting outside areas where the foam blanket may not be contained require calculation by second method.

#### A.3.2.1. Fixed Foam Systems

The quantity of foam concentrate required for protection of machinery spaces must be sufficient for 3 minutes discharge at the required foam solution rate. If the actual rate of flow exceeds the required rate of flow, no increase in quantity of foam concentrate is necessary because this means only that the 6" blanket will be produced in less than 3 minutes. The following example is a typical calculation of foam solution rate, and quantity of foam concentrate required for a machinery-type space.

Assume area to be protected is 3000 ft<sup>2</sup>. Then the required minimum foam solution rate (R<sub>FS</sub>) is:

$$R_{FS} = 300 \text{ ft}^2 \times \frac{1.6 \text{ gpm}}{10 \text{ ft}^2} = 480.0 \text{ gpm}$$

Assume that the foam proportioned introduces a 3% foam concentrate into the water stream at a rate (P<sub>R</sub>) of 3.05% of the foam solution rate.

The quantity of foam concentrate (F<sub>C</sub>) required for 3 minutes operation at the required foam solution rate may be calculated as follows:

$$F_C = R_{FS} \times \frac{P_R}{100\%} \times 3 \text{ minutes}$$

$$F_C = \frac{480 \text{ gal}}{\text{min}} \times \frac{3.05\%}{100\%} \times 3 \text{ minutes}$$

$$F_C = 43.92 = 44 \text{ gallons foam concentrate required.}$$

If the system supplies foam solution at a rate of 500 gpm (in lieu of required 480 gpm), the quantity of foam concentrate required is still only 44 gallons.

#### A.3.2.2. Deck Foam System

Time is the critical feature of deck foam type systems. It is assumed that if a fire is not under control within 15 minutes, that it cannot be extinguished by the ship's crew. Therefore, the quantity of foam concentrate is required to be sufficient for 15 minutes operation at the actual foam solution rate. In determining the actual foam solution rate, no regulation of the water pump to reduce the rate of discharge is permitted. The following is a typical calculation.

Assume tile deck area to be protected is 40,000 ft<sup>2</sup> and largest tank is 2500 ft<sup>2</sup>. The required minimum foam solution R<sub>FS</sub> rate is:

$$R_{FS} = 40,000 \text{ ft}^2 \times \frac{0.016 \text{ gpm}}{\text{ft}^2} = 640 \text{ gpm}$$

$$\text{or } R_{FS} = 2500 \text{ ft}^2 \times \frac{0.24 \text{ gpm}}{\text{ft}^2} = 600 \text{ gpm}$$

Now, assume that hydraulic calculations show that the actual foam solution rate (R<sub>A</sub>) is 680 gpm (in lieu of 640 gpm required). The quantity

of foam concentrate ( $F_C$ ) must then be sufficient for 15 minutes operation at 680 gpm, and may be calculated as follows:

$$F_C = R_A \times \frac{P_R}{100\%} \times 15 \text{ min } \textit{utes}$$

where  $P_R$  = proportioning rate (assumed to be 3.05%.)

$$F_C = \frac{680 \text{ gal}}{\text{min}} \times 0.0305 \times 15 \text{ min } \textit{utes}$$

$$F_C = 311.1 = 312 \text{ gallons foam concentrate required.}$$

For a "polar solvent" system the following is a typical calculation.

Assume the deck area to be protected is 10,000 ft<sup>2</sup>. The required minimum foam solution (foaming, concentrate and catalyst)  $R_{FS}$  is:

$$R_{FS} = 10,000 \text{ ft}^2 \times \frac{0.032 \text{ gpm}}{\text{ft}^2} = 320 \text{ gpm}^2$$

Now, assume that hydraulic calculations show that the actual foam solution rate ( $R_A$ ) is 400 gpm (in lieu of 320 gpm required). The quantity of foam concentrate ( $F_C$ ) must be sufficient for 15 minutes operation at 400 gpm, and may be calculated as follows:

$$F_C = F_C (\text{concentrate}) + F_C (\text{catalyst})$$

$$F_C (\text{concentrate}) = R_A \times \frac{P_R}{100\%} \times 15 \text{ min } \textit{utes}$$

where  $P_R$  = proportioning rate

$$F_C (\text{catalyst}) = \frac{P_R}{100\%} \times 15 \text{ min } \textit{utes}$$

$$(1) \quad F_C (\text{concentrate}) = \frac{400 \text{ gal}}{\text{min}} \times 0.205 \times 15 \text{ min}$$

$$F_C (\text{concentrate}) = 1230 \text{ gallons foam concentrate}$$

$$(2) \quad F_C (\text{catalyst}) = \frac{400 \text{ gal}}{\text{min}} \times 0.0206 \times 15 \text{ min}$$

$$F_C (\text{catalyst}) = 123.6 = 124 \text{ gallons catalyst}$$

#### A.4. FOAM SYSTEM DESIGN

##### A.4.1. Fixed System

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<sup>2</sup> Higher rates may be required on certain products.

In boiler rooms and similar spaces piping, and nozzles are fixed; nozzles must be so located as to spread a blanket of foam over the entire area protected. In general, no point of the area protected should be over 30 feet from a nozzle. If obstructions to the flow of foam are present, additional nozzles may be required.

Nozzles protecting boiler flats should normally be installed to spread the foam under the floor plates (on the lower boiler flat). Foam will usually follow the path of a fuel oil spill in such arrangements, providing the maximum distance from the nozzles is not too great. In machinery spaces the nozzles should be designed to deliver foam to the engine room bilges. The distance from the bilge nozzles to the bilge should be no less than 6 inches. Residual fires above the floor plates in machinery spaces may be extinguished by the additional fire hydrants required. When the foam system is used to protect an oil-fired boiler installation on a boiler flat that can drain to the lower engine room, both spaces should be protected simultaneously. Nozzles should be located near the boiler flat and near the floor plates.

Nozzles may be located at either the deck (boiler rooms) or arranged to spray from the ceiling (pump rooms), depending upon the hazards present in the protected space.

#### A.4.2. Deck Systems

Deck Foam Systems were first required by the 1962 Tank Vessel Regulations in lieu of fixed pipe inert gas smothering systems led to the cargo tanks. This change was invoked to provide an improved fire protection system. With fixed pipe inert gas systems, rupture of a key inert gas line would make it impossible to get inert gas to the fire. Rupture of a tank would make it impossible to maintain an inert gas concentration.

The deck foam system is intended to protect any deck area with the required rate of flow from foam stations (monitors or hose stations) aft of the area. At least 50 percent of the required rate of application shall be from mounted devices. Mounted appliances have greater capacity, greater range, require fewer people to operate and can be put into operation in a much shorter time than hand held devices. However, at least one hand held device shall be provided at each foam station for flexibility during the final stages of extinguishment. Piping and foam stations must be so arranged that ruptured sections of piping in way of a fire may be isolated. With this arrangement, wherever fire occurs, it will be possible to effectively fight the fire by working forward from the after house. (Assuming machinery and foam pumping and proportioning equipment is aft.)

#### A.5. PUMPS

Use of deck foam main is not to interfere with simultaneous use of the fire main. Specific provision is made to use the fire pump for operation of the foam main providing, in fixed systems, that the pump is located outside of the protected spaces. If the foam system supply is taken directly from the fire main a single fire pump must be capable of meeting the hose stream requirements while simultaneously providing the required foam solution rate. Such a system is frequently encountered in partial installations. See typical diagrams included in Part 1 - FIRE MAIN.

The foam main piping shall be used for no other purpose. To permit other use would require quite complex operating instructions, and destroy the concept of a versatile fire protection system which can be brought into immediate use. In addition, there would always be the possibility of pumping all of the foam out through the (say) ballast connection instead of to the fire.

## B. DESIGN AND REVIEW OF SYSTEM

The following is a check-off list procedure for use in the design and review of mechanical foam systems. In case of any doubt, applicable regulations should be consulted to determine exact wording of the requirements.

Applications: Passenger & Cargo Vessels contracted for on or after 19 November 1952

Tank Vessels contracted for on or after 1 January 1962. Mechanical Foam Systems only.

Abbreviations: FX - Fixed Systems  
DK - Deck Systems  
PASS - Passenger Vessels  
CAR - Cargo Vessels  
TK - Tank Vessels

Foam solution, as used in this text, means a mixture of foam concentrate and water before air is introduced and the foam expanded. The term "water rate" is used in the Coast Guard regulations; its meaning is synonymous with that of "foam solution rate," for 3% and 6% concentrate system.

Numbers in brackets refer to the applicable subparts of the regulations.

B.1. A complete submittal for a foam system should contain the following information:

- B.1.1. Manufacturer's name and identification of each principal component by model or part number so that Coast Guard approval may be determined.
- B.1.2. Tabulation of areas (both total cargo and largest tank) protected by foam with supporting area calculations.
- B.1.3. Calculations of foam solution rate and amount of foam concentrate required to protect the above areas.
- B.1.4. A line pressure diagram showing the calculated operating pressure and flow at each foam outlet, at the inlet of the foam proportioner, and at the fire pump outlet. (May be included on system diagram.)
- B.1.5. Tabulated data supporting conditions calculated under (B.1.4) above.
- B.1.6. Detailed arrangements, sections, and elevations of the piping system.
- B.1.7. Fire pump capacity vs. head curve. Source of electric power for foam concentrate pump, if required.

B.2. Determine area of spaces to be protected (see chart, Subpart C).



- B.3. For fixed systems, nozzle spacing and piping arrangements shall be such as to give a reasonably even distribution of foam over the entire area (34, 76 & 95.17-5(a)). If there are obstructions to foam flow from the nozzles, additional foam outlets may be required.
- B.4. For deck systems, foam hydrants and nozzles should be located so that any portion of the open deck cargo area is protected with the required rate of flow (34.20-15(c)). Hydrants and monitors protecting a given area should be arranged so that a fire will not isolate outlets providing the required rate of flow to that area. Sufficient portable foam nozzles and hoses shall be provided for house aft structures to outfit two complete foam stations. The intent is to provide a hack-up station, not to reduce the total number of required stations. For split house configurations sufficient nozzles and hoses shall be located in each house.
- B.5. Determine the foam solution rates required for the areas protected (see chart, Subpart C). In this regard a list of products to be carried shall be submitted for "polar solvent" cargoes.
- B.6. Check line pressure calculations (flow and pressure at each outlet) to assure that the system will meet the requirements of (B.3) above. (See approved sample calculations in foam system design instruction book, e.g. National Foam Instruction Sheet #620 or #626 or Pyrene Design Data Book, JF-17S8 or R~~~36, Rev. 2). A minimum pressure of 50 psi is required at all foam producing outlets.
- B.7. Calculate amount of foam concentrate (3~ or 6~) required to meet the discharge time requirements (see chart). It should be noted that foam concentrate required for fixed systems (boiler rooms, etc.) is based on the required rate while the foam concentrate for deck systems is based upon the actual rate of foam solution flow. In determining this quantity for the deck foam system no manipulation of the fire pump discharge will be permitted.
- B.8. Separate quantities of foam concentrate need not be provided for each space protected, but only for the space requiring the greatest amount (76.17-S(e)(3); 95.17-S(d); 34.17-5(d); 34.20-5(d)).
- B.9. Compare fire pump characteristic curve(s) to conditions calculated under (D.5) above to determine if adequate to meet the required flow conditions.
- B.10. Operation of the deck foam system shall not interfere with the simultaneous use of the fire main system (34.20-5(e)). Fire pumps may be used for other purposes providing one pump is kept available for use on the fire main at all times (34., 76., 95.10-5(e)). See Subpart A for discussion of pump requirements.
- B.11. Controls, valves, foam concentrate container (34., 76., 95.17-10(b), 34.20-10(b)) and pumps (76.17-5(c)(3), 34. & 95.17-5(e)(1)) shall be located outside of the space protected, and be accessible in event of fire in the space protected.
- B.12. Control spaces shall be located convenient to one of the main escapes from the space (34., 76., & 95.17-10(b)), with complete but simple instructions located near the controls (34., 76., & 95.17-10(c)).
- B.13. Deck foam Systems require sufficient block valves to effectively isolate the system in event of damaged piping in way of fire (34.20-15(c)).

- 8.14. Drains and dirt traps shall be fitted where necessary to prevent the accommodation of dirt or moisture (34., 76., 1 95.17-15(d), 34.20-15 (c)).
- 8.15. Two additional fire hydrants are required outside of machinery spaces to extinguish residual fires above the floor plates (34., 76., & 9S. 17-25(a)).
- 8.16. Check part numbers of system components to verify Coast Guard approval. (Piping: 34., 76., & 9S.17-IS(a), 34.20-15(a); Controls, foam concentrate I container: 34., 76., & 9S.17-10(a), 34.20-10(a); Discharge outlets: 34., 76., 1 95.17-20(a), 34.20-20(a)). Model numbers of approved system components are listed in the design instruction booklets of the manufacturers (e.g. National Foam Instruction Sheet No. 620 or 626, Pyrene Design Data Book, JF-1753 or RTM-36, Rev.2) as listed in the Equipment Lists, CG-190. Approved components of more than one manufacturer may not be used in a single installation, except that foam concentrates of more than one manufacturer may be used in a single system if so listed in the approved manufacturer's instruction booklets.

## C. SUMMARY OF AREAS PROTECTED AND FOAM SOLUTION RATES REQUIRED

(For Petroleum-type Cargoes Only)

SPACE PROTECTED	TYPE OF SYSTEM	AREA TO BE PROTECTED	FOAM SOLUTION RATE	DISCHARGE TIME
Boiler Rooms (O) (CAR, PASS, TK)	Fixed	Entire Bilge or Tank Top*	1.6 GPM/10 FT <sup>2</sup> (.17-5(b)(1))	3 Minutes @ Required Rate (.17-5(c))
Pump Rooms (O) (TK)				
Cargo Tanks (O) (CAR & PASS)	Fixed	Entire Liquid Surface Within Usual Range of Trim (.17-5(a)(3))	1.0 GPM/10 FT <sup>2</sup> (.17-5(b)(2))	5 Minutes @ Required Rate
Cargo Tanks (R) (TK)	Deck	Cargo Area, Defined as Maximum Beam Times Longitudinal Extent of Tanks (.20-3) or single largest tank	.016 GPM/FT <sup>2</sup> (entire cargo area)** or 0.24 GPM/FT <sup>2</sup> (area of largest tank)	15 Minutes @ Actual Rate (.20-5(c))
Enclosed Spaces (TK)	Deck	Actual Area of Space	1.6 GPM/10 FT <sup>2</sup> (.20-15(c))	5 Minutes @ Required Rate (.20-15(c))

(O) - Optional in Lieu of Other Systems  
(R) - Required

\*When Used to Protect Oil Fired Boiler Installation on Flat That Can Drain to Lower Engine Room, Both Spaces Shall be Protected Simultaneously (.17-5(a)(2)).

\*\*Deck System Assumes 10 Tanks Per Ship With One Tank on Fire, Flow Rate Then Becomes:

$$\text{Flow Req} = \frac{1.6 \text{ GPM} \times 1 \text{ Tank}}{10 \text{ FT}^2} = 0.016 \text{ GPM/FT}^2$$

## D. INSPECTION AND TESTING

### D.1. INSTALLATION INSPECTION

In accordance with (71.20-15, 31.10-18 etc.) fire extinguishing installations are required to comply fully with the applicable regulations and be in accordance with approved plans.

As with any fire extinguishing system, the foam system should be installed so as to go into operation quickly. During plan review it is attempted to assure that rapid and simple operating is possible. However, there is no substitute for witnessing the actual operation of equipment.

Service contracts for maintenance of foam equipment are not as common as contracts for maintenance of carbon dioxide systems. This makes the Coast Guard inspection particularly important.

To assure that the foam system is properly installed, the following checks are recommended:

#### D.1.1. Deck Foam System

- D.1.1.1. Foam outlets (nozzles), proportioners, and foam concentrate shall be Coast Guard approved as listed on the approved plan or in the Equipment Lists, CG-190. Hoses for the foam system should meet the same requirements as fire hose.
- D.1.1.2. It should be determined that operation of the foam system will not interfere with simultaneous use of the fire main.
- D.1.1.3. The deck foam system should be operated, using water only, to assure that the fire pump and piping system are adequate to deliver at least the required rate of flow at a minimum Pitot pressure of 50 psi. If a foam monitor is installed, due to its high capacity it should be one of the pieces of equipment in this test.
- D.1.1.4. The actual rate of flow obtained under (D.1.1.3) above should be determined. The quantity of foam concentrate should be approximately what is needed for 15 minutes operation of foam system at the actual rate.
- D.1.1.5 Foam should be produced at least at one outlet to observe quality of the foam produced. Production of foam will also assure that the proportioning equipment is functioning properly. Good quality foam should usually be rather fluid, but yet stable enough that it does not drain out into a solution quickly. The appendix of NFPA No. 11<sup>3</sup> gives a more complete description of foam quality. Caution should be used to be certain that water will not get in the foam container to contaminate the foam during testing. It may not be possible to produce test foam in all systems because of contamination problems.
- D.1.1.6 Controls should be clearly marked. Operating instructions should be posted near the control equipment. These instructions should be simple, but must contain sufficient information for proper operation of the system. A diagram of the system is usually essential.

D.1.1.7. Determine, if possible, age of foam concentrate, and suitability for use with equipment installed. Recording batch number of foam concentrate should be sufficient for manufacturer to determine the age if this is not readily available. If in doubt, a sample should be submitted for test as per paragraph 31.10-18(d) of the regulations.

D.1.2. Fixed System

D.1.2.1. Items 1.1.1, 1.1.6 and 1.1.7 should be checked as for deck systems.

D.1.2.2. To assure that the foam piping and outlets are free of obstruction, the system should be flow tested with either air or water. Outlets may be temporarily capped, if necessary, to allow testing of one or two outlets at a time. Water is the preferred test medium as this will give the best indication of the systems efficacy. Water can be directed overboard by hose connections or allowed to flow to the bilges. Again the minimum outlet pressure must be 50 psi. Air can be used to give an indication that pipes are free of total obstruction. However, this will not give an indication of pressure or quantity available. Neither will it pick up smaller obstructions that could eventually clog nozzle when system is brought into use.

D.1.2.3. Each outlet of a mechanical foam system must have a device (foam maker) for introducing air near the nozzle to produce foam. Since test of the fixed system by making foam is not required, absence of these devices will not be readily apparent during testing, and should be carefully verified by visual inspection.

D.1.2.4 When the system protects a boiler flat or similar space, even through there is protection of the lower level, there should be a 9 inch coaming around the flat to assure that a foam blanker will be retained.

D.2. Periodic Inspection

D.2.1. Paragraph 31.10-18(d) outlines the testing procedure for testing deck foam systems biennially. Block valves in the deck foam main should be operated and left in the open position.

D.2.2. A water test of the fixed foam system should also be made.

D.2.3. The foam proportioner (and associated driving equipment if installed) should be operated.

D.2.4. operating instructions and valve markings should be conspicuously located At the time of inspection it is suggested that operation of the system be reviewed with the Chief Engineer to assure his familiarity with equipment.

D.2.5. Check quantity of foam concentrate in tank. Also check quality.

D.2.6. Hose should be tested at a pressure of 100 psi or the maximum pressure to which it will be subjected in service.

IV. WATER SPRAY

## A. DISCUSSION

### A.1. GENERAL

Spray Systems take advantage of the principal advantage of water for fire-fighting purposes: its cooling, ability. breaking the water into small droplets allows it to vaporize more readily and more completely, thus absorbing more of the fire's heat. Water spray systems may be designed to perform any of a number of functions, such as extinguishment of fire, control of fire, or exposure protection. The objective of shipboard installations is complete extinguishment of the fire. In special purpose spray systems, as may be installed aboard LPG carriers for the protection of tanks and house fronts, the function may be to reduce the quantity of heat absorbed by the tank or surrounding structure. These special purpose Systems are discussed later in this chapter.

Water spray is often preferred for protection of pump rooms because there is no danger of asphyxiation as with CO<sub>2</sub> and no mop-up as with foam. The supply of water is inexhaustible.

### A.2. CHARACTERISTICS

There is no fine line of demarcation between sprinkler systems and water spray systems. The differences are primarily in water discharge pattern, water velocity, density of water application, and water droplet size.

Sprinklers have only one basic water discharge pattern, based upon the Underwriters Laboratories requirements. There are well designed rules for sprinkler spacing and size of supply piping, geared to this standard distribution pattern. Aboard ship sprinkler systems may be used to:

- (1) Extinguish fires in Class A (wood, paper) combustibles.
- (2) Protect the structural integrity of the vessel, or
- (3) Confine flammable liquid (Class H) fires in small containers (e.g. automobile tanks) to the location of origin).

All of the above are based upon the minimum water application rate of 0.12 gpm/ft<sup>2</sup> for sprinklers, as required by regulation.

Water spray nozzles, on the other hand, may have any water capacity and discharge pattern. Pipe sizing and nozzle location must be individually engineered, based upon the nozzle characteristics. Water spray nozzles discharge water at a lower velocity and in smaller drop sizes. Nozzles are approved by the Coast Guard upon the basis of tests conducted in mock pump room installations using, diesel oil fuel. Water spray systems are installed aboard vessels to extinguish pump room fires. The rate of water application is considerable higher than for a sprinkler system ranging from 0.21 gpm./ft<sup>2</sup> to 0.46 gpm/ft<sup>2</sup> depending upon the nozzle used.

### A.3. APPLICATION

Water spray is most effective on flammable liquid fires with flash points above the temperature of the water being applied. however, even gasoline fires may be controlled and sometimes extinguished by its use. The extinguishing mechanism of water spray in any fire situation depends upon the type of product burning, degree to which fire has developed, etc. Water spray

extinguishes a fire by cooling, smothering, emulsification, or dilution, or by a combination of these factors. Normally, with fuel oils, and similar high flash point flammable liquids, water reduces the temperature of the burning liquid to below the flash point. This is accomplished by causing a surface emulsion (small drops of water suspended in non-water soluble compounds) of the liquid and by reducing heat transfer back to the liquid surface from the base of the flame. Thus, a fire may be extinguished even before the entire body of the liquid is cooled below the flash point. In addition water applied in a fine spray to hot fires is vaporized as it absorbs the fire's heat, forming steam which tends to smother the fire in enclosed spaces. The spray also cools surrounding structural members reducing the danger of reignition once the fire has been extinguished. Against fires involving water soluble flammable liquids, the water may dilute the liquid, raising its flash point.

#### A.4. DISADVANTAGES

There are two disadvantages of water spray:

- (1) The system is subject to malfunction if not properly tested and maintained, and
- (2) Water spray should not usually be applied directly to live electrical hazards.

#### A.5. EFFECTIVENESS AND APPROVAL

According to numerous articles written on water spray systems, effectiveness of water spray depends upon (1) drop size, and (2) thrust of the spray. The combined drop size and thrust must be sufficient to penetrate through the tremendous "updraft" of the fire to the surface of the burning liquid. Cooling the hot fire gases has little effect, instead the burning surface should be cooled. At the same time, the drop size must be small enough to allow complete vaporization of the water. The smaller the droplets, the more effective their cooling action because of their proportionally greater surface area and resultant higher rate of heat absorption. Coast Guard approval does not take these items into consideration directly, as by a system specification. Rather, approval is based upon actual extinguishment of fires in mock pump rooms.

The manufacturer requesting approval is permitted to arrange nozzles in any way desired, using any rate of application. If the fires are extinguished, the nozzles are approved, the approved application rate to be at least the minimum rate tested. The nozzle pattern and the height of the nozzle above the surface can be no greater than the maximum tested. Data on approved nozzles are included in Section 9 - NOZZLE CHARACTERISTICS.

In any design, at least 50 psig must be available at the most remote outlet.

Mock tests were conducted in 35' x 30' x 25' high pump rooms. Simulated catwalks were installed. It was found that open gratings did not materially reduce the effectiveness of the spray. However, fires under solid partial decks or catwalks low in the space, although suppressed, continued to burn. Additional nozzles under such obstructions are required. In the test arrangement it was found that a temperature of 2000°F was reached within 3 minutes before the spray system was activated. Fires were extinguished in less than one minute.

#### A.6. SPECIAL PURPOSE SYSTEM

For foreign flag vessels entering U. S. ports, and U. S. flag liquefied flammable gas vessels, a water spray system is required for protection of the cargo tanks extending above or mounted on the weather deck. In addition a water curtain shall be provided to screen the cargo area from the deck

house where the crew is normally berthed or employed. The rate of discharge shall be at least 0.25 gpm per square foot of protected surface area. If a deck foam system, required for some other products, is arranged such that an effective water spray could be provided over the tank area, a separate water spray system will not be required. The system shall be designed to the capability of supplying water simultaneously to the deck house screen and the cargo tank area.

This system, it must be remembered, is basically for control and exposure protection. It is not designed to extinguish a fire.

#### A.7. PIPING

There are no specific regulations to govern the site of supply piping or the number of nozzles which may be installed on a single system for water spray systems, as there are for manual sprinkling or carbon dioxide systems. Each installation must be individually engineered. NFPA No. 15 contains sample hydraulic calculations which give reliable results in determining the water demands of spray systems. The hydraulic engineering method contained in that publication is recommended for designing water spray systems aboard ship. Designers should provide detailed hydraulic calculations for each installation to assure that 50 psi will be available at the most remote outlet. Spray system piping shall be of a corrosion resistant material. In addition, since the system is of the "dry pipe" type, piping must withstand temperatures up to 2000-2200<sup>0</sup> F until water can be supplied to the system. The following piping materials are acceptable for water spray installations:

- (1) wrought iron, with 300 lb. malleable iron fittings
- (2) Cupro nickel
- (3) Aluminum bronze
- (4) hard aluminum. brass
- (5) Admiralty metal

Dissimilar metals should not be used in these piping systems. There are cases on record where the unauthorized use of dissimilar metals caused electrolysis and subsequent failure of the system.

Threading compound should not be used. The use of threading compound increases the possibility of clogging strainers by foreign material.

#### A.8. PUMPING CAPACITY

Regulations require that the pump supplying water for the system be reserved exclusively for the system or that one of the required fire pumps be increased by the capacity of the system. These requirements are based upon two assumptions:

- (1) That the water spray system is taken directly from the firemain near the water spray installation, and
- (2) That the water must be available quickly and not be jeopardized by, or jeopardize, the simultaneous use of the fire main system.



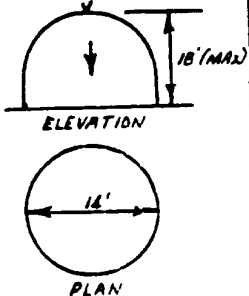
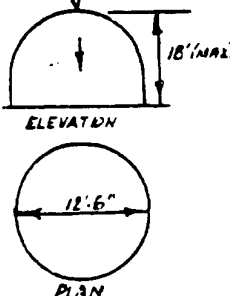
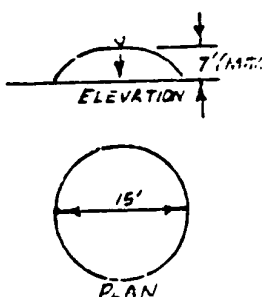
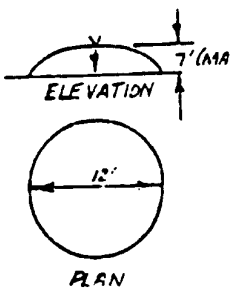
However, there is an additional, equally acceptable alternative for supplying the water spray system. This is done by taking the water supply from the fire pump manifold and locating the water spray system control valve near the pump. A separate supply line is then run to the water spray system, similar to a foam system arrangement. This permits supplying water quickly without interfering with the fire main. This arrangement may even be superior to supplying water from the fire main and locating control valve near the system, since remote starting of fire pumps is not required.

A.9. NOZZLE CHARACTERISTICS

The following tables give nozzle characteristics for various manufacturers.

**A.9.1 Bete Fog Nozzle, Inc.**  
**Discharge Characteristics of CG Approved**  
**Water Spray Nozzles**

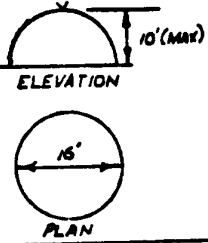
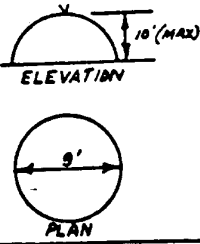
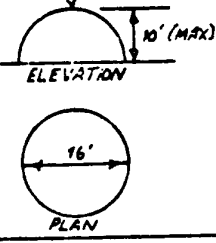
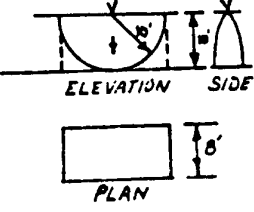
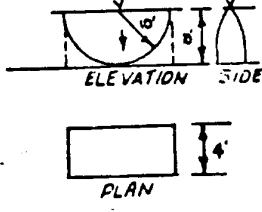
— Test spacing of Bete nozzles was 8'-0" between nozzles, 12'-0" between lines. Maximum distance from nozzle to wall, 10'-0", one line only.

WATER DISCHARGE PATTERN	MODEL	NOZZLE CAPACITY
 <p>ELEVATION 18' (MAX) PLAN 14'</p>	<p>MODEL <b>NSS</b></p>	<p>Nozzle Capacity: 37 GPM @ 50 PSI 52 GPM @ 100 PSI</p> <p>Application Rate (Min.)* 0.42 GPM/FT<sup>2</sup></p>
 <p>ELEVATION 18' (MAX) PLAN 12'-6"</p>	<p>MODEL <b>N3S</b></p>	<p>Nozzle Capacity: 18.4 GPM @ 50 PSI 26.1 GPM @ 100 PSI</p> <p>Application Rate (Min.)* 0.21 GPM/FT<sup>2</sup></p>
 <p>ELEVATION 7' (MAX) PLAN 15'</p>	<p>WIDE SPRAY MODEL <b>NSW5</b></p>	<p>Nozzle Capacity: 37 GPM @ 50 PSI 52 GPM @ 100 PSI</p> <p>Application Rate (Min.)* 0.46 GPM/FT<sup>2</sup></p>
 <p>ELEVATION 7' (MAX) PLAN 12'</p>	<p>WIDE SPRAY MODEL <b>N3WS</b></p>	<p>Nozzle Capacity: 18.4 GPM @ 50 PSI 26.1 GPM @ 100 PSI</p> <p>Application Rate (Min.)* 0.23 GPM/FT<sup>2</sup></p>

\* Application rates are the minimum (Avg.) for which nozzles were tested in mock pump room tests using diesel oil fuel. Design rates should not be less than the test rate. (Minimum rates not included in test data, but derived from test results).

19(1)

A.9.2 Akron Brass Mfg. Co.  
Discharge Characteristics of OG Approved  
Water Spray Nozzles

WATER DISCHARGE PATTERN	MODEL	NOZZLE CAPACITY
	<p>MODEL</p> <p>1" - BM - 54</p>	<p>Nozzle Capacity: 54 GPM @ 100 PSI 37 GPM @ 50 PSI</p> <p>Application Rate (Min.)* 0.46 GPM/FT<sup>2</sup></p>
	<p>MODEL</p> <p>1/2" - BM - 15</p>	<p>Nozzle Capacity: 15 GPM @ 100 PSI 9 GPM @ 50 PSI</p> <p>Application Rate (Min.) 0.27 GPM/FT<sup>2</sup></p>
	<p>MODEL</p> <p>1/2" - DM - 34</p>	<p>Nozzle Capacity: 34 GPM @ 100 PSI 24 GPM @ 50 PSI</p> <p>Application Rate (Min.) 0.32 GPM/FT<sup>2</sup></p>
	<p>MODEL</p> <p>1" - DM - 24</p>	<p>Nozzle Capacity: 24 GPM @ 100 PSI 17 GPM @ 50 PSI</p> <p>Application Rate (Min.) 0.26 GPM/FT<sup>2</sup></p> <p>Test Spacing - 15' O.C.</p>
	<p>MODEL</p> <p>1/2" - DM - 15</p>	<p>Nozzle Capacity: 15 GPM @ 100 PSI 10 GPM @ 50 PSI</p> <p>Application Rate (Min.) 0.32 GPM/FT<sup>2</sup></p> <p>Test Spacing - 10' O.C.</p>

\* Application rates are the minimum rates (Avg.) for which nozzles were tested in mock pump room tests using diesel oil fuel. Design rates should not be less than the test rate. (Minimum rates not included in data, but derived from test results).

## B. DESIGN AND REVIEW OF SYSTEM

This is a check-off type of procedure, listing items which should be considered in designing and reviewing water spray Systems... For interpretation of individual items, reference should be made to the preceding discussion section. In case of any doubt, applicable regulations should be consulted for exact wording of the requirements.

Application: TANK - Contracted for on or after 1 January 1964.  
 PASSENGER & CARGO - Contracted for on or after 19 November 1962.  
 BULK DANGEROUS GOODS -

Where permitted: TANK - Pump Rooms, Lamp and Paint Lockers.  
 CARGO - Oil-fired Boilers<sup>3</sup>, Lamp and Paint Lockers.  
 PASSENGER - Oil-fired Boilers  
 BULK DANGEROUS GOODS - Tanks above deck and deck house fronts

Note: Only carbon dioxide type extinguishing Systems are permitted to be installed for protection of spaces containing internal combustion propelling machinery.

Due to the above, this subpart is written for the protection of pump rooms, where the system is used almost exclusively. Proposals for other installations should follow this subpart as well as SOIAS, 19608 (Chapter II, Regulation 62) as applicable.

(Numbers in parentheses refer to applicable regulations)

- B.1. Select nozzles to be used: must be Coast Guard approved (34.25-20) and (153.32-20). Approval also designates minimum pressure (50 psi) and maximum height that nozzle may be installed above the protected area.
- B.2. Capacity and arrangement of the system must be such as to effectively blanket the area protected (34.25-5(a)) and (153.32-5). Compliance with this requirement is related to which approved nozzles are used, and includes the following factors:
  - (1) Minimum rate of water application for which nozzle was tested.
  - (2) Spray pattern of the nozzle, and
  - (3) Height of the nozzle above the protected area (34.25-5(b)) and (153.32-5(b')).

These factors are more fully discussed in the preceding subpart.

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<sup>3</sup> Recent changes to the regulations eliminate the specific requirements for fixed water spray systems from the Passenger and Cargo Vessel regulations. This is because:

- (1) No installations of water spray systems for protection of oil-fired boilers on the vessels have been proposed, and
- (2) The 1960 SOLAS Convention increases the requirements for such systems protecting oil-fired boiler installations. Under 1960 SOLAS, the System is required to be charged to the necessary pressure at all times with the provision that a pressure drop in the system shall automatically start the pump.

- B.3. To check the pattern, show the nozzle locations on plan and elevation views and sketch in water distribution pattern of the nozzles. Obstructions to distribution may require additional nozzles (34.25-5(b)) and (153.32.5(b)).
- B.4. In the event that considerable piping or pumping requirement is installed above the highest spray nozzle, it may be necessary to provide additional nozzles to protect this equipment (see NFPA No. 15, 25.40).
- B.5. Water supply must be from outside of space protected and in no way dependent upon power from the space protected (34.25-5(c)).
- B.6. Pumps supplying water for the system shall be reserved exclusively for the system or the capacity of one of the required fire pumps, as set forth in 34.10, shall be increased by the required capacity of the system so that this system may be used simultaneously with the fire main system (34.25-5(c)) and (153.32-5(d)). however, if the water spray system is supplied from the fire pump manifold in such a way that it would not interfere with simultaneous use of the fire main system, and in such a way that it can be put into service quickly, this would be acceptable.
- B.7. The control valve shall be outside of the space protected and as convenient as possible to one of the escapes from the space (34.25-10) and (153.32-10). However, if the water spray system is supplied from the fire pump manifold, as described in (B.6), the control valve may be near the pump. It is not necessary to be able to start the pumps from the control station.
- B.8. Complete, but simple, operating instructions shall be posted near the controls (34.25-10). Controls shall be marked as required by 35.40-18.
- B.9. Piping shall be of a heat and corrosion-resistant material (34.25-15(a) and (b)) and (153.32-15(a) and (b)). See discussion section for list of acceptable materials. Threaded joints should be metal to metal; no threading compound should be used.
- B.10. Drains and dirt traps shall be fitted where necessary to prevent accumulation of dirt and moisture (34.25-15(d)) and (153.32-15(d)). Line strainers are required to have a total clear area equal to five times the area of the pipe in which it is installed. Approval of spray nozzles also includes approval of the associated strainer, if required.
- B.11. Water distribution and water supply for the system should be verified by hydraulic calculations. Good engineering is not a complete substitute for testing the installation, but it is important to resolve system deficiencies in the design stage.

## C. INSPECTION AND TESTING

- C.1. Water spray nozzles shall be Coast Guard approved, and must be the same type as indicated on the approved drawing.
- C.2. Water supply (pump capacity) should be checked by operating water spray system and firemain simultaneously. Minimum pressure at the most remote spray nozzle should be 50 psi.

- C.3. Water distribution pattern of the spray system should be checked. This may be done by entering space as the system is operated. If the system is operating properly, the space should be filled with a dense water fog. (Flush with fresh water after testing).
- C.4. Following flow tests of the system, the line strainer and all nozzle strainers should be checked and determined to be free of obstruction.
- C.5. Check location of control valves. They must be near the fire pump or convenient to one of the main escapes from the spaces.
- C.6. Complete, but simple, operating instructions shall be posted near the controls.

## V. MANUAL SPRINKLING SYSTEM

### A. DISCUSSION

#### A.1. GENERAL

Aboard U. S. vessels, sprinkler systems are employed in only very limited locations. In method I (SOLAS), primary dependence is placed upon structural fire protection rather than automatic sprinkler protection. This is in contrast to the British method (method II) in which combustible construction is permitted in combination with a complete sprinkler system. (Method II employs an automatic in lieu of a manual sprinkler system).

A sprinkling system will accomplish two things:

- (1) It will extinguish fires in class A (wood, etc.) combustibles, as well as high flash point (above 200<sup>0</sup>F) combustible liquids.
- (2) It will control the heat output from flammable liquid (e.g. gasoline) fires and at the same time offer protection to the overhead of the protected space.

In installations protecting vehicular decks the system should be designed to protect the structural integrity of the vessel, confine the fire to the location of origin, and wash the flammable liquid to a safe location. Installation on vehicular decks, such as aboard ferry vessels, is the primary marine use of sprinkler systems in this country.

There is no sharp line of demarcation between sprinkler Systems using standard sprinklers and water spray systems. The primary differences are in water discharge pattern, water velocity, density of water application, and water droplet size.

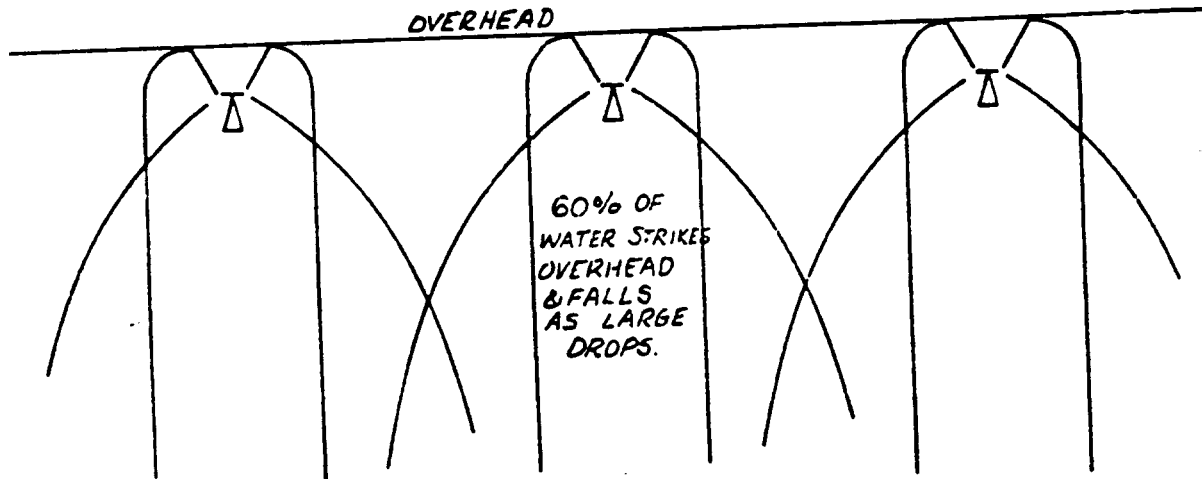
Sprinklers have one basic discharge pattern and must distribute water in accordance with a standard distribution pattern established by Underwriters Laboratories. There are well developed standards for pipe sizing and sprinkler head spacing based upon this standard discharge pattern. Regulations require a minimum application of 0.12 gpm/ft<sup>2</sup>. Sprinkler systems, as installed aboard vessels, are primarily for protecting the structural integrity of the vessel limiting the spread of fire, and controlling the amount of heat produced.

Water spray nozzles are of different sizes and distribution patterns. These systems are usually designed to provide greater water densities in smaller drop sizes than are sprinkler systems. Pipe sizes, nozzles and nozzle spacing must be selected for each installation so as to effectively distribute the required quantity of water. Water spray systems are more effective in extinguishing fires in low flashpoint flammable liquids.

#### A.2. TYPES OF SPRINKLERS

When the regulations were written, what is now termed the "old-type" sprinklers were then in common use. Coast Guard regulations were written around such sprinklers.

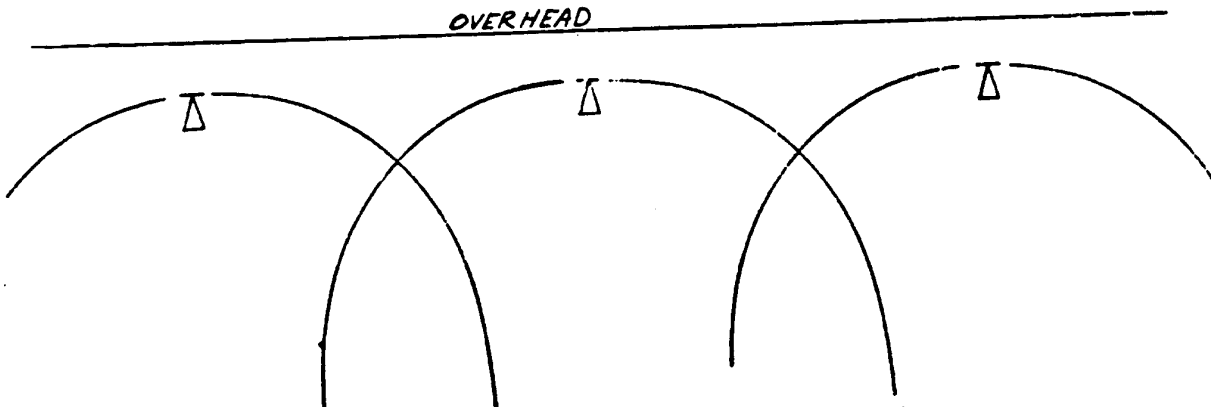
The old-type sprinklers were designed to spray a portion of the water against the over head for the purpose of cooling it.



**Figure V.A.1 Discharge Pattern of Old-Type Sprinklers**

This was the basis upon which the "effectively spray the overhead" provision of the regulations was developed.

Subsequent to publication of these regulations, however, the "standard" sprinkler head was developed. This sprinkler does not direct any water against the overhead. Tests have proven that with standard sprinklers the water distribution is more uniform and the system is more effective. The overhead is given equivalent protection.



**Figure V.A.2 Discharge Pattern of Standard Sprinklers**

Use of "standard" sprinklers should be encouraged in lieu of the "old-type" because they afford better protection at similar spacings. Since the regulations were written in contemplation of "old-type" sprinklers, their use is permitted. "Old-type" sprinklers may be installed in either upright or pendent position. If "standard" sprinklers are installed in the pendent position, they must be so designed; the designation "pendent" will be marked on the deflector. Distinction between "old-type" and "standard" sprinklers may be made by examining the manufacturer and model designations stamped on the frame or deflector of the sprinkler. Reference to underwriters Laboratories Fire Protection Equipment List will indicate sprinkler type. In installations, "standard" sprinklers may be used to replace the "old-type;" but "old-type" replacement of "standard" sprinklers should not be permitted.

### A.3. SPACING OF SPRINKLERS

No portion of the overhead shall be more than 7 feet from a sprinkler.

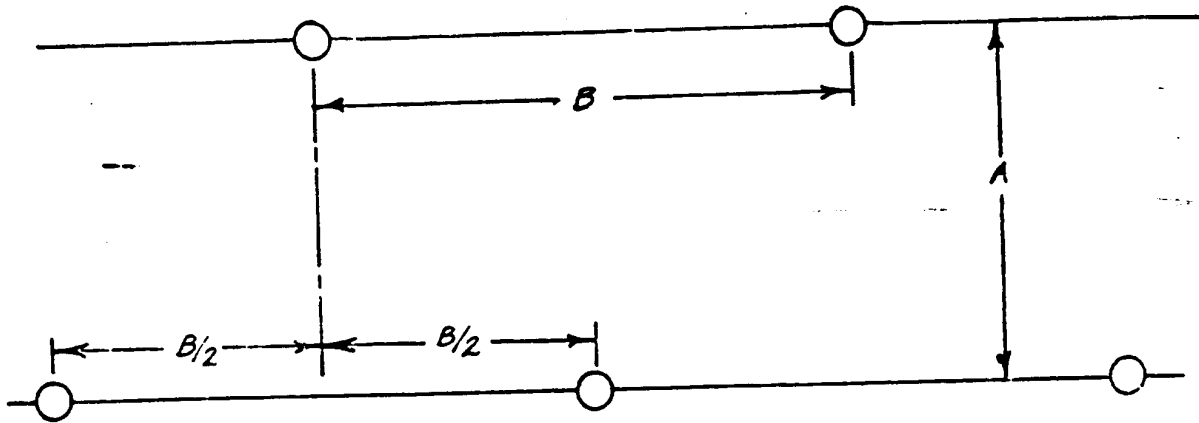


### A.3.1. Old-Type Sprinklers

Spacing of "old-type" sprinklers should be based on one sprinkler to not more than 100 ft<sup>2</sup> of deck area, regardless of Pitot pressure at the sprinkler head (15 psi Pitot is, of course, the minimum). Greater spacing should not be allowed since the major portion of the water is directed against the overhead.

If sprinklers on alternate lines are not staggered,

the seven feet from sprinklers is controlling, and the arrangement must be such that  $\sqrt{A^2 + B^2}$  is 14 feet or less.



**Figure V.A.4 Sprinklers on Alternate Lines Staggered**

If sprinklers on alternate lines are staggered, the 100 ft<sup>2</sup> limitation becomes the controlling factor, and  $A \times B$  must equal 100 ft<sup>2</sup> or less.

Staggered spacing is preferred; it gives better water distribution. If the spacing is other than full staggered, the sprinklers should be considered non-staggered. Regulations were developed in contemplation of non-staggered or fully-staggered arrangements. With 15 psi Pitot at the head, the 5/8" diameter sprinkler will deliver 12 gpm, meeting the 12 gpm/100 ft<sup>2</sup> requirement.

### A.3.2. Standard Sprinkler

Due to the superior water distribution of "standard" sprinklers, the "maximum of seven feet from a sprinkler" criteria may be applied in all instances. With staggered spacing, this would permit one sprinkler to cover an area greater than 100 ft<sup>2</sup>. If this is done, the minimum Pitot pressure at the most remote outlet must be increased such that the required 12 gpm per 100 square feet is still applied to the deck area. The Pitot pressure necessary to deliver the required quantity of water through a 3/8-inch diameter sprinkler may be estimated in accordance with the following section.

#### A.3.2.1. Sprinkler Characteristics

$$Q = 29.83cd^2\sqrt{P}$$

where  $Q$  = flow (gpm)

$C$  = coefficient of discharge (0.75)

$d$  = orifice diameter (9 inches)

$P$  = Pressure (psi)

$$Q = K\sqrt{P}$$

where  $K = 3.15$

at 15 psi Pitot pressure,  $Q = 12.2$  gpm.

If a standard sprinkler is designed to protect  $120 \text{ ft}^2$ , the lowest Pitot pressure required would be:

$$Q = 120 \text{ ft}^2 \left( \frac{.12 \text{ gpm}}{\text{ft}^2} \right) = 3.15\sqrt{P}$$

$$\text{or } P = \left( \frac{14.4}{3.15} \right)^2 = 20.9 \text{ psi (minimum)}$$

Similar calculations can be made for any individual design.

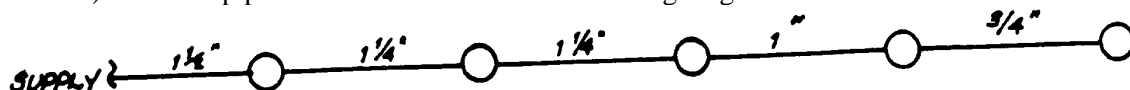
End sprinklers may be a distance from the bulkhead equal to one half of the line distance between heads. Reference should be made to NFPA No. 13 for standard spacing of end sprinklers on alternate lines and spacing of lines adjacent to bulkheads.

Care must be taken in referring to NFPA No. 13 as criteria for vessel installations. Sprinklers for land installations have a  $\frac{1}{2}$ " diameter opening; the Coast guard specifies a  $\frac{3}{8}$ " diameter opening.

#### A.4. PIPE SIZING

The pipe-sizing schedule listed in the Coast Guard regulations is arranged so that if 15 psi Pitot pressure is available at the most remote sprinkler head, it will be available at every head in the system. This is true providing there is no appreciable difference in elevation head between the sprinkler heads.

The number of sprinkler heads listed in the piping schedule which may be served by a given diameter of pipe refers to the total number of sprinklers. The table states that a  $\frac{3}{4}$ " pipe may serve one sprinkler, a 1" pipe may serve two sprinklers, etc. For example, assume the end pipe of a system is  $\frac{3}{4}$ " in diameter and serves one sprinkler. The next length of piping must be 1" in diameter. The two sprinklers served by the 1" pipe means the one on the  $\frac{3}{4}$ " pipe plus one (not two) on the 1" pipe. This is illustrated in the following diagram:



Detailed hydraulic calculations are usually not required. However, in systems of unusual design or where there is a question regarding the system's adequacy hydraulic calculations demonstrating that 15 psi will be available at all outlets should be prepared.

## A.5. DRAINAGE

Consideration should be given to drainage of water from sprinkled Spaces. Gasoline will float on the surface of the water and, although suppressed, will continue to burn. Drainage should be to a safe location such as over-board drains which will not allow the burning liquid to flow into openings below. Drainage must also be adequate so as to preclude a stability problem.

A.6. RELIABILITY

As with water spray systems, the greatest drawback of a sprinkler system is its unreliability. Sprinkler lines and sprinkler heads have a tendency to clog with foreign matter if not tested frequently and flushed with fresh water after testing. Fire pump suction seachests for sprinkler pumps have become so clogged as to cause the fire pump motors to burn up due to lack of testing. If properly designed and maintained, a sprinkler system can be among the most effective fire fighting mediums aboard a vessel. However, long experience has demonstrated that because of the difficulty of testing without damaging the interior and finishings, that proper maintenance is seldom performed and the system will not operate as designed.

A.7. NAVY SPRINKLER SYSTEMS

Frequently on MSC and missile resupply ships a magazine-type sprinkling system of Navy design is proposed for protection of missiles, ammunition lockers and similar spaces. The systems proposed generally cover rather large areas and are highly automated. In addition, standard Navy equipment such as nozzles, etc. are used in these systems. The water sprinkling rate for these systems is generally equal to or slightly less than the required rate for systems contemplated by the Coast Guard. Due to the extremely sensitive nature of spaces protected, the systems are designed to operate automatically within a period of a few seconds.

Coast Guard regulations do not contemplate these high capacity, automatic sprinkler systems, nor hazards of the nature which they are designed to protect. For these reasons, Navy design Systems, including Navy (or Mil Spec) equipment, and sprinkling rates may be accepted on special service vessels, the nature of whose contents are not contemplated by Coast Guard regulations without a compromise of vessel safety. This is providing that (1) accessible manual valves are available to open or close the system manually should this be necessary, and (2) that operation of the Navy-type sprinkler system does not interfere with simultaneous operation of the vessel's firemain. In other words, the fact that the system is basically, of Navy design does not reduce any requirements considered necessary for the safety of other portions of the vessel.

In these designs special consideration should be given to the quantity of water discharged from the sprinkler system, as excessive quantities may seriously impair the vessel's stability.

Navy type automatic detection Systems may also be accepted in conjunction with these Systems.

When sprinkler Systems are proposed in areas required to be so protected by Coast Guard regulations, a Coast Guard approved system must be installed. A Navy system is not acceptable.

## B. DESIGN AND REVIEW OF SYSTEMS

This procedure is an outline of essential items which should be considered in designing and reviewing sprinkler systems. For interpretation of individual items, reference should be made to the preceding discussion section. In case of any doubt, applicable regulations should be consulted for exact wording of requirements.

Application: PASSENGER VESSELS - Contracted for on or after 19 November 1952<sup>4</sup>

CARGO VESSELS - No provisions, if permitted or required under equivalency paragraph, apply passenger vessel rules

TANK VESSELS - No application

- Where Required:
- (1) Vehicular decks (defined as a deck designed for the carriage of automobiles with fuel tanks containing gasoline, with one or both ends open, such as is found on ferry vessels).
  - (2) Cargo spaces which are accessible during the voyage. (This may also include protection of automobiles in specially designed automobile carriers providing special considerations are given to drainage).

Numbers in parentheses refer to applicable subparts of the regulations.

B.1. Check over-all arrangement of vessel to determine number and arrangement of sprinkler zones required.

B.2. The following guidelines should be used in determining required zoning:

- (1) Separate zones may be used for each deck (76.23-5(a)).
- (2) On any particular deck, spaces separated by "A" or "B" class bulkheads may be zoned separately.
- (3) In common areas (that is, a large space on a single deck that is -not subdivided by "A" or "B" class bulkheads) the number of zones shall be as required by table 76.23-5(b).

B.3. Zones in common areas shall be approximately the same size. Zones of this type shall be arranged to overlap so that the end heads of adjacent zones cover an identical area (76.23-5).

B.4. Layout the sprinkler arrangement. Sprinklers must be arranged such that:

- (1) No portion of the overhead is more than 7 feet from a sprinkler head (76.23-10(b)(1)), and
- (2) At least 12 gpm is applied to each 100 ft<sup>2</sup> of deck area (76.23-10 (a)).

The requirement appearing in the regulations that the overhead is to be effectively sprayed is applicable only if "old-type" sprinklers are used.

For a more complete discussion of item B.4. see preceding Subpart A.3.

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<sup>4</sup> Passenger Vessel Regulations also have provisions for automatic sprinkling systems, but they are seldom, if ever, installed aboard U. S. vessels.

- B.5. Sprinklers shall be so located that there is no obstruction of the distribution of water by frames or girders. At the same time the sprinklers should be located close enough to the overhead to afford protection to the overhead. A maximum distance of 16 inches below the frames is recommended. (See NPPA No. 13 (7110 and 7120) as reference).
- B.6. Check pipe sizing based upon number of sprinklers served. (Table 76. 23-10(e)). If piping is sized in accordance with the schedule (that is one sprinkler on a 3/4" pipe, two<sup>5</sup> on a 1" pipe, etc.) and 15 psi Pitot pressure is available at the end sprinkler head, it will be available at every head in the system (providing there is no appreciable difference in elevation heads).
- B.7. Locate control valves for system. Must be outside of space protected and accessible in event of fire in the protected space (76.23-15(a)). The control shall be marked as required by 78.47-15.
- B.8. Determine pumping requirements. Pumps must be sufficient to operate all sprinklers in a single zone at a minimum Pitot pressure of 15 psi (see item #B.6). In addition, on vessels over 750 gross tons, the capacity shall also be sufficient to operate the second largest zone (76.23-10(d)(i)). Fire pumps may be used to supply water to the sprinkler system as described above, providing the combined pump capacity is sufficient to simultaneously meet the hose stream requirement of 76.10-5(c) in addition to the sprinkler system.
- B.9. Pipes shall be securely supported, and where necessary, protected against injury (76.23-20(c)).
- B.10. Pipe and fittings shall meet the applicable requirements of Subchapter F (Marine Engineering).
- B.11. Drains and dirt traps shall be fitted where necessary to prevent accumulation of dirt or moisture (76.23-20(d)).
- B.12. Piping shall be used for no other purpose (76.23-20(e)).
- B.13. Sprinkler heads are to be of the open-type, 3/8 inch in diameter (76. 23-10(b) (1)).
- 8.14. Provide sprinklers of an approved type (76.23-2S). However, the Coast Guard does not specifically approve sprinklers. Sprinkler heads listed by Underwriters Laboratory are accepted as meeting this requirement. "Standard" sprinklers are preferable to "old-type" sprinklers. See preceding Subpart of further discussion. Part numbers of approved components should be listed on the drawings(s) for ease of identification during plan review and inspection.

## C. INSPECTION AND TESTING

It is difficult to perform effective tests of sprinkler system installations due to the nature of the spaces which they protect. Water damage can easily be incurred within accommodation or storage areas. However, it is essential that the system be tested as thoroughly as possible at regular intervals. Installation of the sprinkler equipment is of little value if it does not function properly in time of emergency. The following testing procedure is recommended.

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<sup>5</sup> The number of sprinklers that may be supplied by a given size pipe refers to the total number of sprinklers. For example, if the end pipe is 3/4" diameter, it may serve one sprinkler. If the next section of pipe is 1" in diameter, it may serve a maximum of one additional sprinkler, making a total of two sprinklers (one on 3/4" and one on 1") served by the 1" diameter pipe.

## C.1. INITIAL INSPECTION

C.1.1. Determine adequacy of pumping capacity to supply the largest (or two largest) sprinkled zones. Preferably this test should be made prior to the installation of easily damaged equipment by actually pumping water through the largest sprinkled zone(s) and measuring the Pitot tube pressure at the most remote outlet. This pressure must be a minimum of 15 psi. If the fire pumps are used, the required number of fire hoses must be operated simultaneously with the sprinkler system. If performing an actual system test is not possible, the water demand for the sprinkler system may be approximated. A rough estimate of the water demand would be:

- (1) Approximately 14 gpm per head in the largest zone if separate pumps are installed or
- (2) Approximately 18 gpm per head plus required number of hose streams if the fire pumps are used.

The pump(s) should be capable of delivering this quantity of water through a number of hose streams at a minimum Pitot tube pressure of 25 psi plus the difference in elevation head, if any, between the hose stream and the highest sprinkler(s) in case (1) or a minimum Pitot tube pressure of 50 psi in case (2). (Flush with fresh water after testing). If separate pumps are provided, and it is not possible to cross-connect the pump with the firemain to test as described above, a alternate means of measuring pump capacity must be devised.

C.1.2. Review valve and piping arrangement to assure ease of system operation. Control valves should be so located that they are accessible in event of fire in protected space. Fire pumps must also be accessible in event of fire in protected space.

C.1.3. Review sprinkler spacing and location. Sprinklers should be located as shown on the approved plans and such that there is no obstruction to water distribution. Sprinklers should usually be not lower than 16" below deck frames.

C.1.4. Check pipe sizing based upon the number of sprinklers served. Pipes should be securely supported.

C.1.5. Determine that approved sprinkler heads are used. Coast Guard regulations call for 3/8" orifice diameter sprinklers. Other, including larger, diameters should not be accepted unless specifically approved on plans. Large diameters may mean that the pumping capacity is inadequate and the over-all effectiveness of the system is reduced. Open-type sprinklers are required.

C.1.6. Drains and dirt traps should be installed to assure proper maintenance of the system.

C.1.7. Assure that control valves are properly marked to identify zone which they control.

## C.2. PERIODIC INSPECTIONS

C.2.1. If practicable operate the system with water. If this is not possible, remove a sprinkler or flushing connection near the most remote sprinkler in the system. All other sprinklers must be plugged to prevent damage. More than one connection or sprinkler may be removed if

deemed necessary. Connect suitable hose etc. to flow water overboard or to other safe location from the selected outlets. Systematically remove other sprinklers and plug other openings to further test the zone as necessary. operate pumps, discharging water through the selected outlets, to assure that the lines are free of obstruction. (Flush with fresh water after testing).

- C.2.2. Visually inspect all open sprinklers to determine that they are free of obstruction.
- C.2.3. Operate control valves and verify that they are properly marked.
- C.2.4. Open drain traps to eliminate any water trapped in system.
- C.2.5. Verify that dirt traps are not clogged or obstructed.

If the system shows signs of excessive corrosion, has not been tested for a considerable period of time, or does not function properly in the partial discharge test described in 2.1, an actual operational test is recommended. The performance record of sprinklers aboard vessels has been poor at best. Further information on the maintenance and cleaning of sprinkler systems is contained in NFPA, No. 13A - Care and Maintenance of Sprinkler Systems, the Handbook of Industrial Loss Prevention (Factory Mutual), and the NFPA Fire Protection Handbook.

## VI Halon Systems

### A.1. General

Total flooding halon fire extinguishing systems are appropriate for enclosed spaces where fires involving electrical equipment or gaseous and liquid flammable materials may occur. The extinguishing agents used in these systems are halogen substituted hydrocarbons. Several different halon agents exist with variations in the amounts of carbon, chlorine, bromine, and fluorine in the compound. The accepted nomenclature system for these compounds describes the molecular composition of the agent. Each agent is given a number, the first digit represents the number of carbon atoms, the second fluorine, the third chlorine, the fourth bromine, and the fifth iodine. Terminal zeros are dropped. The three most common halogenated extinguishing agents at present are: Bromochlorodifluoromethane (Halon 1211), Bromotrifluoromethane (1301), and Dibromotetrafluoroethane (Halon 2402). Halon 1301 is the only halogenated agent currently accepted by the Coast Guard for fixed shipboard fire extinguishing systems. Other halons are unacceptable because they are either highly toxic themselves, or they can form unacceptable amounts of toxic products of decomposition when exposed to fire. portable fire extinguishers widely used in the past contained Halon 104 (Carbon Tetrachloride) or Halon 1011 (bromochloromethane). Due to the toxicity of both these agents, their marine use was banned by the Coast Guard in 1958. Currently, both Halon 1301 and Halon 1211 portable extinguishers are available, which carry Coast Guard marine approval.

Halon 1301, even though acceptable for shipboard use, is somewhat toxic; however, if discharged properly, the toxic effects are minimal. Halon 1301 is a colorless, odorless gas which chemically interacts with the combustion process to inhibit combustion. Although it is similar to carbon dioxide in application and storage, its extinguishing action is produced by an entirely different process. Halon 1301 chemically interrupts the process which produces combustion, while carbon dioxide extinguishes flames by displacing the atmosphere to effectively reduce the oxygen content below a point where combustion can occur. Halon 1301 should not be used to protect hazards involving chemicals capable of rapid oxidation in the absence of air, combustible or reactive metals, and metal hydrides. Additionally, the use of Halon 1301 on Class A materials has not been thoroughly researched by the U. S. Coast Guard at present and is therefore not acceptable for the protection of cargo holds when carrying general cargoes.

Halon 1301 systems are designed to limit the production of toxic products of decomposition. If Halon 1301 is heated above 900°F (482°C), it breaks down to form hydrogen fluoride, free bromine and carbonyl halides. Full scale tests involving flammable liquid fires, conducted at the Coast Guard Fire and Safety Test Facility have shown that if Halon 1301 is discharged into a burning machinery space in 10 seconds or less, the amount of toxic decomposition products formed are of less consequence than the normal combustion products such as carbon monoxide.

### A.2 Coast Guard Approval of Halon 1301 Systems

At present, Title 46 of the Code of Federal Regulations does not contain any provisions for the design or requirements of Halon 1301 systems aboard commercial vessels. In essence, the approval of these systems is based upon a provision within the Code of Federal Regulations that grants to the Commandant of the Coast Guard the authority to allow new or unique systems, if it is adequately demonstrated that the proposed system is equivalent to the existing system required by the regulations. Carbon dioxide total flooding fire protection systems are the systems to which Halon 1301 systems must prove equivalence. Therefore, Coast Guard approved Halon 1301



systems are required by Federal Law to be designed with an equivalent degree of fire protection capability and reliability. Where basic deviations in design occur due to the use of the Halon 1301 agent, specific adaptation to the regulations have been developed.

The basic design philosophy of carbon dioxide systems, however, has been retained for halon systems:

- a. The protected space must be evacuated before the system is discharged. Pre-discharge alarm is required.
- b. The agent storage containers must be located outside of the protected space, except for spaces less than 6000 ft<sup>3</sup> and modular type halon systems.
- c. Two separate and distinct actions must be performed to discharge the agent.
- d. Manual type release devices are required; automatic release is permitted only for spaces less than 6000 ft<sup>3</sup>.
- e. Detailed instructions must be provided at the remote release station to explain alternate means of discharging the system.

### A.3 Specific Areas of Concern Involving Halon Agents

1. One feature of halon fire extinguishants that must be kept in mind is the possible hazard they may present to personnel. The agents have a certain degree of inherent toxicity; however, if designed and handled properly, the halon agents and systems present no greater risk than carbon dioxide extinguishing equipment and usually much less. Of the current halon agents, 1301 is considered the only halon fire extinguishant which may be used for total flooding applications onboard vessels. The Coast Guard requires a minimum 6% by gross volume concentration (volume 1301/volume air) of the agent for fire extinguishing Systems. At this concentration, toxic effects are minimal; however, personnel should not be exposed to a 7% concentration for more than one minute and a 10% concentration may well be regarded as unsafe for human exposure.

To adequately protect personnel from these hazards, the Coast Guard requires the protected space to be evacuated before Halon 1301 discharge. Additionally, a warning sign is required at each entrance to the protected space, warning personnel that re-entry of the space, after the system is discharged, should not be attempted without self-contained breathing apparatus.

Toxic products of decomposition are formed when Halon 1301 is exposed to flames. If Halon 1301 is discharged in 10 seconds or less, causing rapid extinguishment of flames, the amount of toxic products formed is of little or no consequence. The amount of these toxic products of decomposition formed can be minimized by discharging the halon system as soon as possible after fire discovery. More halon breakdown will occur if the fire has the opportunity to burn freely and heat the metal structure within the protected space. This would seem to suggest that automatic detection and release of the halon agent would be desirable. In buildings, this concept is viable; however, onboard vessels, automatic release is not practical in all cases. To properly extinguish a fire, operating machinery within the protected space must be shut down prior to agent discharge. If a vessel were navigating in

a high density shipping channel, an automatically released fire extinguishing system could shut down the main propulsion plant and ship's service generators when needed most.

An engineering trade-off has therefore been made, requiring for all spaces greater than 6000 ft<sup>3</sup>, manual release of agent, and evacuation of the protected space to protect personnel from potential toxic products of decomposition of the halon.

2. A second problem that may be encountered with Halon 1301 concerns the protection of diesel engines. If carbon dioxide is injected into a running diesel engine, the engine will stop. This has not been observed with Halon 1301; in fact, the engine may even speed up. It is possible that if a diesel engine were to scavenge Halon 1301, toxic products of decomposition from the Halon 1301 breakdown under the high cylinder pressures within the diesel could be released through the diesel exhaust system. Coast Guard design requirements mandate the automatic shutdown, prior to halon discharge, of all diesel engines which receive intake air from the protected space.

#### A.4 system Types

The purpose of this guide is to explain the requirements for engineered type Halon 1301 systems. There are two other types of Halon 1301 systems which are reviewed by the Coast Guard. Both of these are approved as pre-engineered type systems. The approval for these systems will indicate factors such as maximum-permissible pipe lengths, number of elbows, etc. These systems are as follows:

Approval Number - 162.035/1/1 - Bromotrifluoromethane Systems for Hydrofoil Craft.

These systems are for limited installation in unmanned spaces up to a maximum volume of 2250 cubic feet.

Approval Numbers - 162.029/1/0  
162.029/3/0  
162.029/4/0  
162.029/7/0  
162.029/8/0  
162.029/9/0  
162.029/10/0

Halon 1301 systems for installation in uninspected pleasure craft.

#### B.1 General Arrangements

The basic arrangement for Halon 1301 systems is similar to approved carbon dioxide systems. The agent cylinders are manifold together and located outside of the protected space. A releasing control should operate one or two pilot cylinders and a stop valve control must be provided to prevent agent discharge if the pilot cylinders are accidentally tripped. The agent is in turn piped to the protected space and discharged through nozzles. The general arrangements shown in Appendix A are acceptable.

Currently, there are no Halon 1301 systems which resemble low pressure carbon dioxide systems. Several manufacturers, however, are currently vending a "modular" type system, which consists of

a number of agent containers mounted in various locations throughout the protected space. The containers are not connected to a manifold, but are arranged to discharge individually. The releasing mechanisms are either electric or pneumatic. The review of these systems is done by Headquarters, because of the complex nature of the system control hardware. A very detailed review is done to insure that control and supervisory circuitry will function in the marine environment. A reliability study is also conducted on most electrical components.

## B.2 Halon 1301 Concentration

The extinguishing effectiveness of Halon 1301 is highly dependent upon the concentration of the agent in the protected space. Tests conducted by the Coast Guard have shown that for normal shipboard protection, a 6% concentration of Halon 1301 of the total or gross volume of a machinery or other space can effectively extinguish flammable liquid fires in that space. The amount of agent necessary to form this concentration must be calculated for the lowest range of temperature expected in that space. Basically, this is because the specific volume (ft<sup>3</sup>/lb) of Halon 1301 vapor varies with the ambient temperature

A 6% halon design concentration calculated at the lowest ambient temperature expected in the space with no deductions being made for machinery could cause the concentration in the protected space to be as high as 7% - 7.4% under actual conditions because temperatures within most machinery spaces are usually greater than 700F under normal operating conditions.

It is felt that this concentration is justifiable for shipboard halon systems for the following reasons:

1. Evacuation of the protected space is required- Automatic release of machinery space halon systems is not permitted because vital ships navigating and propulsion equipment could be stopped at inopportune times. This may cause higher temperatures to be reached within the protected space before agent release which in turn could form unacceptable amounts of toxic halon decomposition products.
2. A 7% concentration is approximately the inerting concentration required for most marine fuels - According to NFPA Standard I2AD the inerting concentration should be used where large amounts of fuel are available which could be atomized or sprayed from broken fuel lines or fittings.

## B.3 Determination of Necessary Quantity of Halon 1301

The minimum design concentration of Halon 1301 for machinery spaces, turbine enclosures, or pump rooms containing diesel fuel, gasoline, or crude oil and other similar petroleum products is 6% of the gross volume of the space. If other flammable or combustible materials are present in the protected space, higher concentrations of halon may be needed.

To calculate the necessary weight of Halon 1301, the volume of the protected space must first be determined. This volume is the gross volume, i.e. no deductions are made for machinery or any other contents.

The gross volume is then multiplied by the mass flooding factor. The mass flooding factor in pounds per cubic foot is calculated from the specific volume of the halon vapor at a given temperature. when the mass flooding factor is multiplied by the volume of space, the result is the quantity of Halon 1301 in pounds necessary to give a 6% concentration. The mass flooding factors

are dependent upon the temperature within the protected space. Standard mass flooding factors have been determined for specific areas. These values should always be used unless circumstances require some special consideration. The mass flooding factor for pump rooms is .0289 lb/ft<sup>3</sup> (0°F) and for machinery spaces and turbine enclosures is .0270 lb/ft<sup>3</sup> (32°F).

If unique conditions arise, the necessary quantity of Halon 1301 may be calculated as follows:

$$W = \frac{V}{s} \quad \frac{C}{100 - C}$$

W = weight of Halon 1301 required, lbs.

C = Halon 1301 Concentration, % by volume

V = Volume of protected space (ft<sup>3</sup>)

s = Specific volume of the Halon 1301 vapor. This value is calculated with the following formula:

$$s = 2.2062 + .005046T$$

T = Design Temperature, °F

#### B.4 Effects of Ventilation

The extinguishing potential of total flooding Halon 1301 Systems depends upon the "tightness" of the Space, and any leakage of agent from the space will reduce this effectiveness. If there are any openings to the space which cannot be completely closed, a discharge test of the system may have to be conducted to ascertain if an extinguishing concentration can be reached and maintained.

In spaces where power ventilation is installed, the ventilation system must be shut down prior to agent discharge. The shutdown of the ventilation must be automatically accomplished by the operation of the halon system releases. Sufficient time for the rundown of the ventilation must also be allowed before the release of halon.

In the event that ventilation cannot be expediently shut down, an additional quantity of agent must be provided to compensate for the effects of ventilation. The following formula should be used to determine the necessary total amount of agent:

$$Q = \frac{0.01CET}{s \left[ 1 - e^{\frac{-ET}{V}} \right]}$$

Q = Lbs of halon

C = Halon 1301 Concentration % by volume

E = Ventilation rate, ft<sup>3</sup>/sec.

T = Time in sec. (10 sec. max.)

$V$  = Volume of protected space,  $\text{ft}^3$

$S$  = Specific volume of Halon 1301 vapor,  $\text{ft}^3/\text{lb}$ . (See Section B.3)

$e$  = Natural logarithm base, 2.71828

#### B.5 Overpressurization of Protected Space

Due to the high speed discharge of the superpressurized Halon 1301, it will almost always vaporize as it leaves the discharge nozzle, resulting in adiabatic cooling of the protected space and causing a temporary pressure drop. This pressure drop has a tendency to counteract the pressure rise expected because of the partial pressure of the added 6% halon concentration. The halon-air mixture will eventually cause a pressure rise, as heat is transferred into it from the surrounding bulkheads and decks, but this pressure rise is gradual and can usually be vented through any available small openings.

#### B.6 Agent Storage Containers

Halon 1301 is stored in metal containers in liquid form, and is superpressurized with dry nitrogen to one of two pressures (at  $70^\circ\text{F}$ ): 360 or 600 psig. The quantity of Halon 1301 that is stored in each container varies among manufacturers and generally ranges up to a maximum of 250 lbs.

All containers on a common manifold must be of the same size and must contain the same quantity of Halon 1301 to insure an equal rate of flow into the manifold from each container. Manifolded cylinders must be secured with a substantial mounting bracket to prevent damage.

Cylinders should be located as near to the protected space as possible, and the following criteria must also be met:

1. The cylinders must be located outside of the protected space, except for spaces less than  $6000 \text{ ft}^3$ .
2. The temperature range the cylinders may be exposed to is between  $130^\circ\text{F}$  and  $-20^\circ\text{F}$ . Spaces containing Halon 1301 cylinders must be ventilated or heated to maintain the ambient temperature within these limits.
3. Halon 1301 cylinders are fitted with an overpressure relief device (normally a frangible disc) which will allow the relief of excessive pressure within the cylinder. If the cylinders are located adjacent to the protected space, enough heat may be conducted through bulkheads or decks to rupture the overpressure disc. Should this occur, the halon storage room would be filled with agent, and very little, if any, would be available to extinguish the fire. Therefore, common bulkheads and decks between halon storage rooms and protected spaces must be constructed to A-60 class.

#### B.7 Controls

The releasing mechanisms for halon systems are similar to those used for  $\text{CO}_2$  systems. The usual type of mechanical releases are cables. The pull handles of these cables should not require a pull of more than 40 pounds nor a movement of greater than 14 inches to release the contents of the halon

containers. Also, the cables as well as the remainder of the releasing mechanism must be protected from the weather. Pneumatic releases are also acceptable on certain systems.

Instructions explaining the system operation and containing a schematic diagram of the piping layout should be posted at each pull box or stop valve control, and in the halon storage room. The instructions should be as follows:

1. The instructions should give specific locations and instructions of where system components are located in relation to where the person attempting to operate system is standing.
2. The instructions should also be easy to comprehend in a brief period of time.
3. At each pull box, two sets of instructions should be posted. The first set of instructions should state in some form --- In case of fire in (protected Space) operate extinguishing system by pulling lever, operating valve, etc. --. The second set of instructions should state in some form ---If the extinguishing system fails to operate, go to (some specified location) and follow instructions posted there ---. A map or plan should be included with this instruction, showing the operator exactly where he must go to find the secondary release.
4. The instructions should be printed in letters large enough to be read from a distance of several feet.
5. In the cylinder storage room, a general schematic of the entire system should be posted showing the various sections of the system. To facilitate rapid comprehension of the arrangement, each section should be numbered, color coded, or named. Each pilot valve and stop valve should in turn be numbered, named, or color coded. An instruction list should be posted with a heading stating in some terms --- Alternate means of operating fire extinguishing system in case of failure of remote release devices Each protected space should be listed with appropriate instructions for each space, e.g.

Boiler Room: operate blue stop valves (3) and blue cylinder valves (2)

Cargo hold #3: operate stop valve number seven and release 14 CO<sub>2</sub> cylinders.

These instructions should state which valves to operate and how many should be operated. If stop valves are located remote from the cylinder storage room, the instructions should also explain where to find the valve.

6. The instructions should be securely mounted and should be permanently inscribed on metal or plastic plates. Temporary paper instructions which are sealed in plastic may be posted until inscribed instructions can be fabricated.

These guidelines are general in nature, exact wordings and descriptions on nameplates are left up to the manufacturer.

A remote release and control for appropriate stop valves or direction valves must be located as near as possible to at least one exit of the protected space.

## B.8 Warning Devices

Alarms which depend on no source of power other than pressure must be installed to signal the impending discharge of the Halon 1301 system. These devices are arranged to sound an alarm when the system release is operated but prior to agent discharge. A discharge delay mechanism must be installed in the halon piping to allow an escape period after the discharge alarm begins sounding. The alarm must be audible throughout the entire protected space while machinery is running. A sign must be posted immediately adjacent to the alarm explaining its purpose.

A warning must be posted at each entrance to the protected space warning personnel not to enter the space without self-contained breathing apparatus after the halon system has been discharged.

#### B.9 Hydraulic Calculations of Agent Flow

The flow of Halon 1301 through piping requires careful evaluation. Because both liquid and gaseous halon are flowing simultaneously, a condition of two-phase flow can exist. Unlike the calculation of carbon dioxide flow, the calculation of halon flow is very critical.

All Halon 1301 systems should be balanced, i.e., all branches should be roughly of equal length and similar flow rates. This is particularly important if the system is designed to discharge simultaneously into several spaces. When splitting the halon flow at tees, an exact determination of how much agent flows in each direction cannot be guaranteed through unbalanced branches. If a tee and unbalanced piping is used to divide the halon flow into two separate spaces, it is possible to have an insufficient concentration in one of the spaces.

For all submittals, the percent of agent in piping should be evaluated. This is the ratio of the internal volume of the entire discharge piping network to the volume of the Halon 1301 in the storage containers. If the percent of the agent in piping ratio exceeds 100%, there will not be a sufficient amount of agent to completely fill the piping during discharge. The accuracy of flow calculations depends upon having the discharge piping completely filled with agent. If the ratio exceeds 125%, a discharge test should be conducted to evaluate the performance of the system.

#### Example #1

A tank vessel has a pump room with a volume of 130,000 cubic feet and which is normally unmanned. The installed ventilation system operates at the rate of one complete air change per minute and when shut down, requires an approximate rundown time of 35 seconds. Good engineering practice would suggest that one would design the system to shut down the ventilation with the actuation of the system, and by means of the time delay prevent the discharge of the agent into the hazard area until the ventilation has completely run down. However, for the purposes of illustration of the calculation technique, the time delay is designed for 25 seconds, with the ventilation system operating at full capacity during the 10 seconds of agent discharge.

Under the above conditions, the Halon 1301 quantity required to produce a 6% concentration at 0°F (Section B.3 for pump rooms) at the end of a discharge -period of 10 seconds with a ventilation rate of 130,000 cubic feet/minute is calculated using the formula in section B.4:

$$Q = \frac{0.01CET}{s \left[ 1 - e^{\frac{-ET}{V}} \right]}$$

$$\text{At } 0^{\circ}\text{F., } s = 2.2062 + 0.005046(T) = 2.2062 \frac{ft^3}{lb}$$

$$E = 130,000 \frac{ft^3}{min} = 2166.6 \frac{ft^3}{sec}$$

$$T = 10 \text{ seconds}$$

$$Q = \frac{0.01(6) \left( 2166.6 \frac{ft^3}{sec} \right) (10 dec)}{2.2062 \frac{ft^3}{lb} \left[ 1 - e^{\frac{-2166.6(10)}{130,000}} \right]} = \frac{1299.9}{2.2062 \times (0.1535)} = 3838 \text{ pounds}$$

### Example #2

A system is to be installed in a floating nuclear power plant located off the coast of Key West, Florida. The temperature in the protected space will not normally drop below 70°F. Determine the required quantity of halon needed to protect a volume of 37,000 ft<sup>3</sup>.

$$W = \frac{V}{S} \left[ \frac{C}{100 - C} \right]$$

$$\text{where } S = 2.2062 + .005046T$$

$$T = 70^{\circ}\text{F}$$

$$S = 2.2062 + .35322$$

$$S = 2.55942 \text{ ft}^3/\text{lb}$$

$$W = \frac{37,000 \text{ ft}^3}{2.55942} \frac{6\%}{100 - 6\%} = 923 \text{ lb}$$

### C.1 Review of Systems

The following information is required for the complete review of a Halon 1301 submittal:

- a. General schematic of system and description of space~to be protected.
- b. Piping and fitting schedule.
- c. Drawings of components to include:
  - i. Storage containers and DOT rating
  - ii. Discharge heads
  - iii. Release mechanisms
  - iv. Any detection system parts



- v. Nozzles
- vi. Alarms
- vii. Valving
- viii. Warning and instruction signs
- ix. Any other component part (e.g. ventilation shutdown, time delay, etc.)
- d. Calculations verifying the following:
  - i. Design concentration 6 percent at lowest possible temperatures anticipated within the protected areas.
  - ii. Hydraulic calculations to demonstrate discharge within 10 seconds at ambient temperature not to exceed 70°F.
- e. System manual containing:
  - j. Operation instructions
  - ii. Maintenance instructions

To eliminate a complex review for each system submitted, a standard parts list will be developed by Headquarters. This will eliminate the need for the vendors to submit component drawings with each system. The standard review procedure will be to check, first of all, the appropriateness of the system for the protected space, then the design temperature, Halon 1301 concentration and quantity. The hydraulics of the system should be checked with the procedures outlined in NFPA standard 12A. Each of the part numbers should be checked to see if they are listed on the standard parts list. Should any problems arise, they may be referred to Headquarters.

#### D.1 Design and Review of System

1. Check protected space and determine if total flooding Halon 1301 system is correct application. Halon should not be used to protect Class A materials.
2. Check volume of protected space. If volume exceeds 6000 ft<sup>3</sup>, automatic release is not permitted.
3. Check boundaries of protected space to ascertain if the halon concentration can be maintained. Note if ventilation systems can be shut down prior to agent release.
4. Determine quantity of Halon 1301 needed. Extra halon must be supplied to compensate for unclosable vent openings or operating ventilation systems. Check if quantity of Halon 1301 supplied is sufficient.
5. Divide quantity of halon in-pounds by 10 seconds to get required flow rate in lb./sec. Check the sum of flow rates of nozzles to determine if provided system has an adequate flow rate.

6. Check cylinder location. Cylinders must be located externally to protected space except for automatic systems and certain specially approved systems. Cylinder storage room must have temperatures between -20<sup>0</sup>F and 130<sup>0</sup>F. Automatically released systems may have cylinders within protected space.
7. Cylinders must be securely mounted, and must be removable for weighing. Each cylinder must have a pressure gage. If cylinders are mounted adjacent to protected space, common bulkhead or deck must be A-60.
8. A pressure relief device must be installed in each cylinder, and the manifold.
9. Check nozzle arrangement to determine if uniform distribution is provided.
10. Piping must be schedule 40 or heavier, and must be galvanized. Piping must extend 2 inches beyond the last nozzle of each branch line to prevent clogging. Pipe exceeding 4 inches in diameter must be schedule.60. Fittings must be 300 lb class malleable iron or other acceptable as listed in 46 CFR Parts 50 to 63.
11. Check piping supports to determine that piping is securely fastened. Aluminum piping supports are unacceptable.
12. Check manual release devices. Two distinct and separate actions should be required to operate the system. A schematic diagram of the system and a procedure for discharging the system if the remote release devices are non-functioning should be posted by each release Station.
13. Check ventilation and other operating machinery in protected space. Devices must be provided in the Halon 1301 system to shut down ventilation before agent release. Diesel engines which intake air from the protected space must be shut down automatically prior to agent release.
14. Check to determine if discharge delay allows adequate time to evacuate protected space before agent is released. The pre-discharge alarm must be loud enough to be heard in the protected space while machinery is running.
15. Check component part numbers with the Coast Guard approved parts list.
16. Check hydraulic calculations according to NFPA Standard 12A. Certain manufacturers use different methods to compute flow. A deviation of 15% of the required nozzle pressures is acceptable.
17. Determine percent of agent in piping. This should not exceed 125%.

#### D.2 Halon 1301 Systems Inspection Procedures

1. The weight of each cylinder must be checked. If a weight loss of more than 5 percent is noted, the cylinder must be replaced or recharged.

2. The pressure of each cylinder must be checked. If a pressure drop (adjusted to temperature) of more than 10 percent is recorded, the cylinder must be replaced or recharged. Cylinder pressures will vary with temperature; the following chart is provided as a guide:

	360 psi system	600 psi system
Temperature	Pressure	Pressure
40 <sup>0</sup> F	275 psig	500 psig
50 <sup>0</sup> F	300 psig	530 psig
60 <sup>0</sup> F	330 psig	565 psig
70 <sup>0</sup> F	360 psig	600 psig
80 <sup>0</sup> F	395 psig	640 psig
90 <sup>0</sup> F	430 psig	680 psig
100 <sup>0</sup> F	470 psig	730 psig

3. Predischage alarm must be checked and operated with dry air or nitrogen if necessary. The alarm should be audible throughout the space with machinery operating.
4. Remote release mechanisms must be checked to insure that cables and pulleys are free to move and that the mechanism operates properly.
5. Switches for automatic shutdown of equipment must be checked and tested if necessary.
6. Check to see if all openings to the space can be completely closed.
7. Legible operating instructions detailing release and alternate method of release must be posted at each entrance to the protected space.
8. Visually check all piping for breaks, corrosion, obstructions, etc. If necessary, blow out piping with pressurized air.
9. Check all mounting brackets for proper support.
10. Check date of last hydrostatic test; cylinders must be hydrostatically tested every 12 years.

### D.3. Installation Test Requirements

1. Halon 1301 piping systems should be tested as outlined in 46 CFR 76.15-15 (J). The test pressures used shall be equal to one and one half times the design pressure of the system.

### REFERENCES

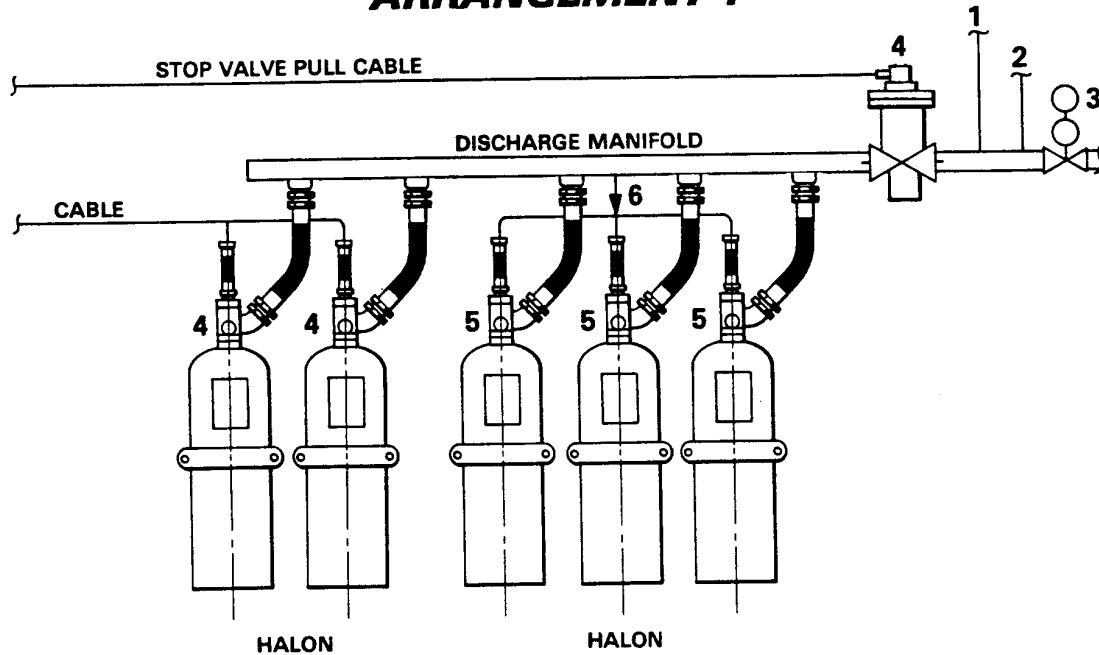
- (1) "An Investigation into the effectiveness of Halon 1301 (Bromotrifluoromethane CBrF<sub>3</sub>) as an extinguishing agent for Shipboard Machinery Space Fires." D.F. Sheehan, March 1972, U.S. Coast Guard, Office of Research and Development.
- (2) N.F.P.A. Standard \*12A

Approved General Arrangements for Halon 1301 Systems

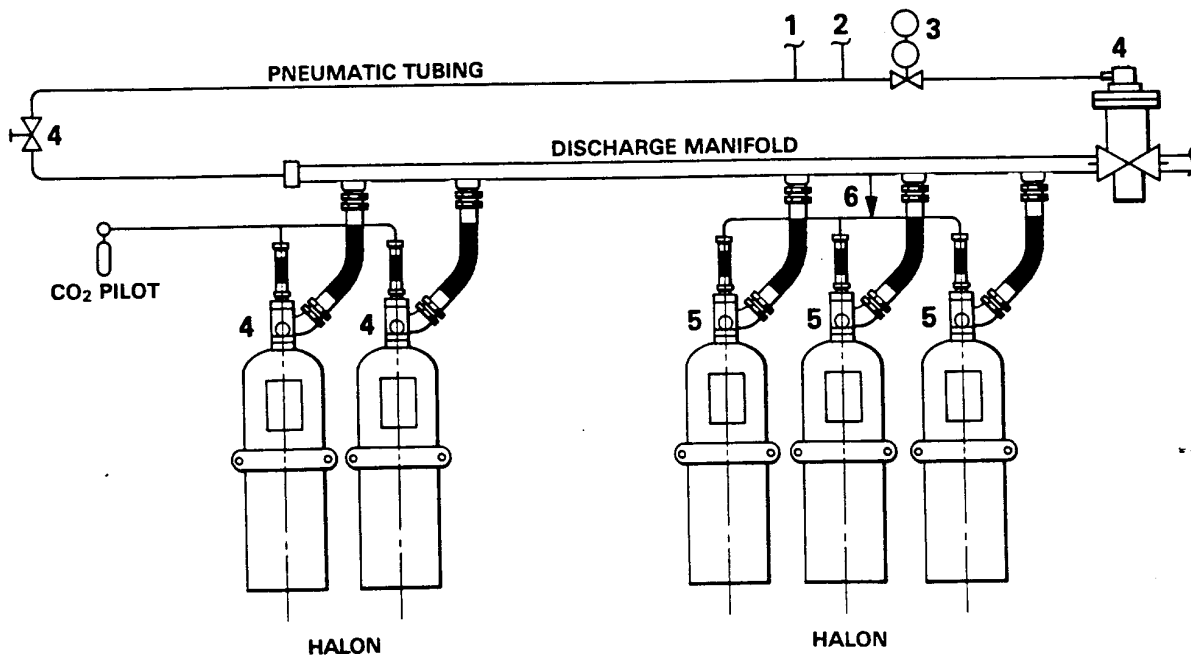
**KEY**

1. TO PRESSURE OPERATED ALARM.
2. TO PRESSURE OPERATED SWITCHES.
3. TIME DELAY.
4. VALVE CAPABLE OF MANUAL OPERATION.
5. PRESSURE OPERATED VALVE. NO MEANS OF MANUAL OPERATION.
6. CHECK VALVE.

**ARRANGEMENT 1**



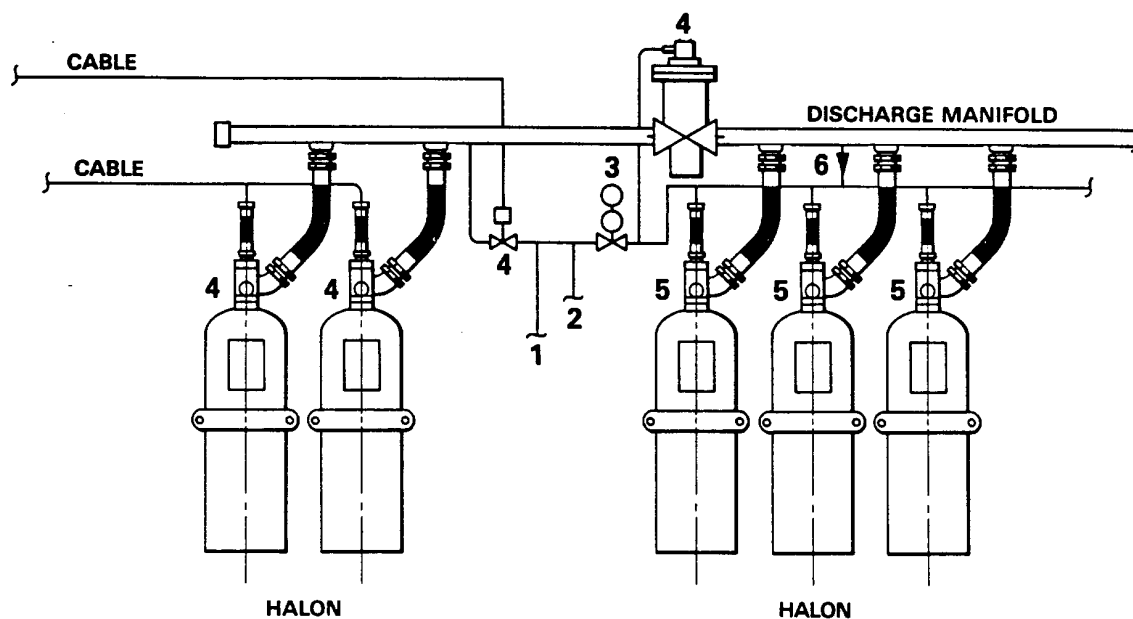
**ARRANGEMENT 2**



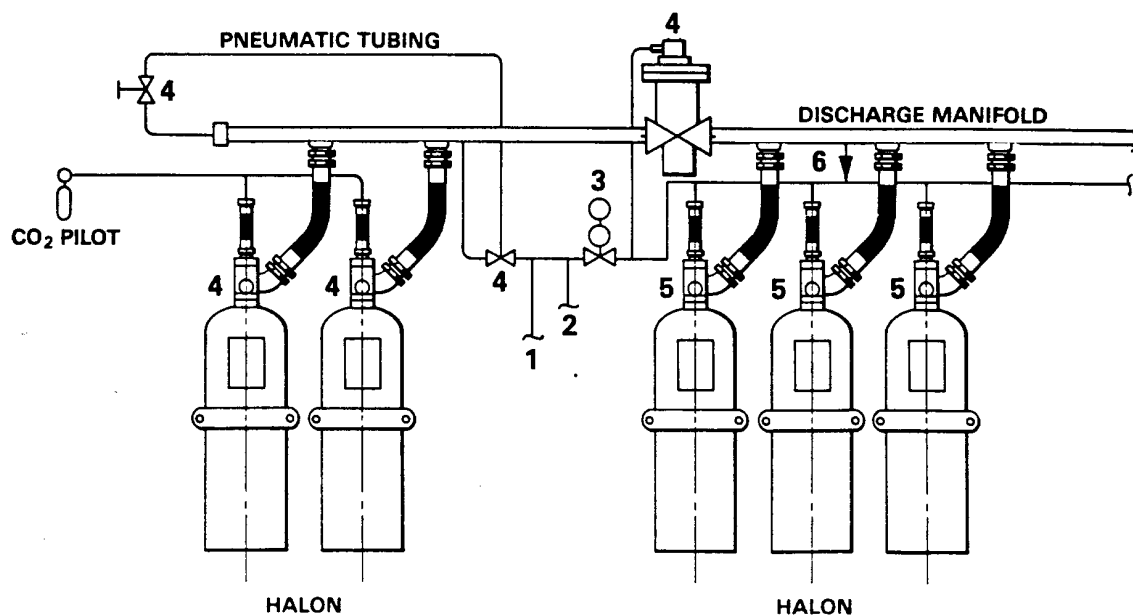
**KEY**

1. TO PRESSURE OPERATED ALARM.
2. TO PRESSURE OPERATED SWITCHES.
3. TIME DELAY.
4. VALVE CAPABLE OF MANUAL OPERATION.
5. PRESSURE OPERATED VALVE. NO MEANS OF MANUAL OPERATION.
6. CHECK VALVE.

**ARRANGEMENT 3**



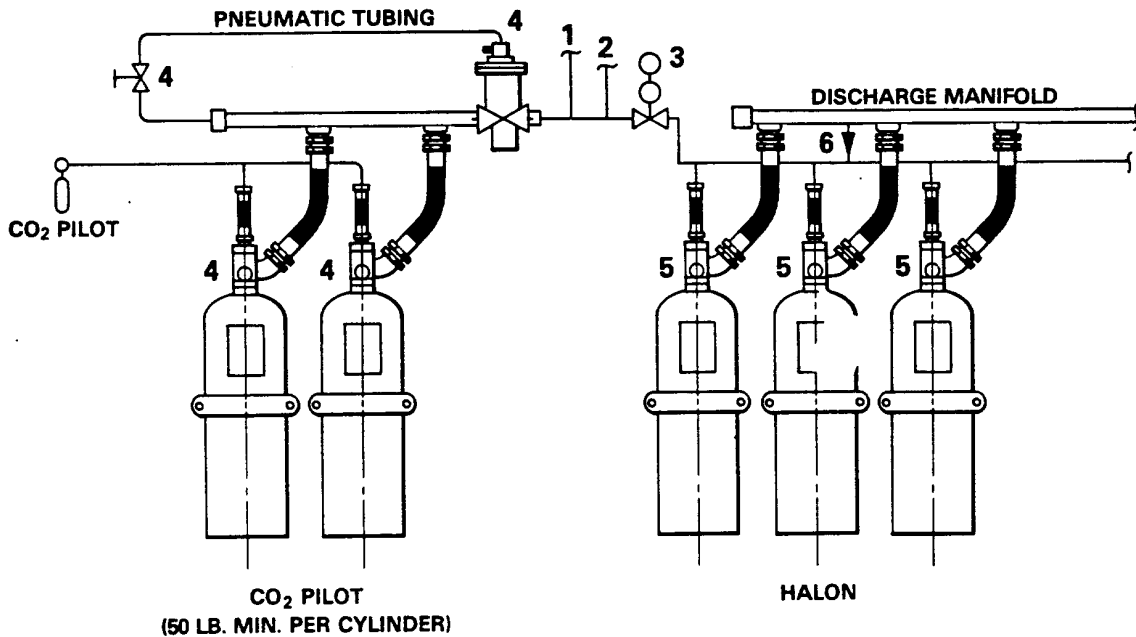
**ARRANGEMENT 4**



**KEY**

1. TO PRESSURE OPERATED ALARM.
2. TO PRESSURE OPERATED SWITCHES.
3. TIME DELAY.
4. VALVE CAPABLE OF MANUAL OPERATION.
5. PRESSURE OPERATED VALVE. NO MEANS OF MANUAL OPERATION.
6. CHECK VALVE.

**ARRANGEMENT 5**



**ARRANGEMENT 6**

